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FIRE CONTROL RADAR SPECIAL CIRCUITS

INFORMATION, EXPERIMENTS AND APPLICATIONS

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BUREAU OF NAVAL PERSONNEL

NAVPERS 92213A VOL. 2

DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA

DEPARTMENT OF THE NAVY
BUREAU OF NAVAL PERSONNEL
WASHINGTON, D. C. 20370

FIRE CONTROL RADAR SPECIAL CIRCUITS
TRAINEE'S GUIDE, NAVPERS 92213A
VOLUME TWO

1. This publication has been prepared for use as a text at the Fire Control Technician School, Class "A", and at other locations where such subject matter is required. The Instructor's Guide, NavPers 92212A, is the complementing text for the course.

2. Corrections and recommendations for changes to this publication are invited. Commanding Officer, Service School Command, Great Lakes, Illinois, has been assigned clearing house responsibility for evaluating and compiling recommended improvements and for submitting them to the Chief of Naval Personnel in the form of a proposed change. Users of this course material are requested to submit their recommendations directly to the command having clearing house responsibility with a copy to the Chief of Naval Personnel (Attn: Pers-C1122).

3. This publication does not supersede any existing publication.

H. O. Johnson

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Instructional Standards
and Materials Division

NAVPERS 92213A VOL. 2

FIRE CONTROL RADAR SPECIAL CIRCUITS

TABLE OF CONTENTS

Topic No.	Title	Page
1.	Introduction to Test Equipment	1
2.	Multimeter (VOM) and Vacuum Tube Voltmeter (VTVM).	4
3.	Capacitance, Inductance, and Resistance Bridge ZM11/U	20
4.	Special Test Probes	24
5.	Cathode Ray Tube	32
6.	General Purpose Oscilloscope OS-8E/U.	40
7.	Synchroscope AN/USM-32	60
8.	Synchroscope AN/USM-117	74
9.	Oscilloscope Tektronix 545A.	88

LIST OF ILLUSTRATIONS

No. Title Page

1. Basic VOM . . . 4
2. VOM Circuit Loading Effects . . . 5
3. Multimeter AN/PSM-4A, Front View with Cover Open . . . 6
4. (A) Basic VTVM (B) Tube Characteristics . . . 8
5. DC VTVM Circuit . . . 9
6. VTVM Ohmmeter Circuit . . . 10
7. Senior Voltohmyst WV-98A Panel . . . 11
8. VOM Effects . . . 13
9. Chassis Voltage and Resistance Diagram . . . 16
10. Chassis Voltage and Resistance Diagram . . . 17
11. Simplified Schematic of Capacity Checker . . . 20
12. Capacitance Loading Effect . . . 24
13. Probe with Isolating Resistor . . . 25
14. Isolation Probe . . . 26
15. Isolation Probe . . . 27
16. (A) Direct Probe for Typical Scope (B) Scope Input Circuit . . . 28
17. Low Capacitance Probe . . . 28
18. Low Capacitance Probe Combined with Scope Input Capacitance . . . 29
19. Cathode Ray Tube . . . 32
20. CRT Internal Construction . . . 34
21. Horizontal Sweep Generation . . . 35
22. Unblanking Waveform . . . 36
23. Combined Horizontal and Vertical Inputs . . . 37
24. Push-pull Signals on CRT Deflection Plates . . . 38
25. Oscilloscope, Block Diagram . . . 40
26. Lissajous Patterns . . . 43
27. Phase Comparison . . . 44
28. Phase Difference Patterns . . . 45
29. Oscilloscope, Block Diagram . . . 47
30. Controls and Input Connections of the OS-8C/U Oscilloscope . . . 49
31. Controls and Input Connections of the OS-8C/U Oscilloscope . . . 51
32. Types of Oscilloscope Graticules . . . 52
33. Quadrant System . . . 53
34. Amplitude and Time Measurement . . . 54
35. Scope Calibration . . . 56
36. Preliminary Adjustment . . . 57
37. Frequency Comparison . . . 58
38. Frequency Comparison - Lissajous Patterns . . . 58
39. Lissajous Patterns . . . 59
40. AN/USM-32, Front Panel Controls . . . 60
41. AN/USM-32, Front Panel Controls . . . 62
42. AN/USM-32, Front Panel Controls . . . 64
43. AN/USM-32 Synchroscope, Functional Block Diagram . . . 67
44. Blocking Oscillator Output . . . 70
45. AN/USM-117 Front, Panel . . . 74
46. AN/USM-117 Front, Panel . . . 76

LIST OF ILLUSTRATIONS (Continued)

No.	Title	Page
47.	AN/USM-117 Block Diagram	79
48.	Method of Determining Frequency	82
49.	Blocking Oscillator Output	84
50.	Oscilloscope 545A	89
51.	Dual Trace Preamplifier	90
52.	Oscilloscope 545A	91
53.	Oscilloscope 545A	93
54.	Time Base Diagram	96
55.	Pulse Jitter Measurement	97
56.	Low Capacitance Probe, Type P6000, Schematic Diagram	97
57.	Probe Adjustment Waveforms	98
58.	Oscilloscope 545A Block Diagram	99/100

HOW TO USE THIS TRAINEE'S GUIDE

TECHNICAL TRAINING

This Trainee's Guide has been prepared to place emphasis on the practical training of the technician in the operation and maintenance of fire control equipment. All Navy technicians are expected to be craftsmen - not engineers or designers - and they will learn their skill by doing.

PUBLICATION

This publication, now in your custody, is your guide for use during this portion of the course. Since it will be forwarded to you after you have completed the course, it is suggested that you use its pages for any useful notes.

STUDY ASSIGNMENTS

Study assignments in this publication will be made by your instructor. Some time will be available for study during the regular school day, but additional study will be necessary. Assignments, covering the material to be discussed the following day, will normally be made at the end of the school day.

SAFETY NOTICE

WARNING

The attention of all hands is directed to Section V, Chapter 67 of Bureau of Ships Technical Manual or superseding instructions on the subject of safety.

Extreme caution must be observed when working with fire control systems and associated equipments. Dangerous voltages are present at all times, and contact with them can result in permanent injury and death. While every practical safety feature has been incorporated in this equipment, the following rules must be observed strictly.

KEEP AWAY FROM LIVE CIRCUITS:

Operating personnel must at all times observe all safety regulations. Do not change tubes or make adjustments inside equipment with high-voltage supply on. Under certain conditions dangerous potentials may exist in circuits with power controls in the off position due to charges retained by capacitors. To avoid casualties always remove power, and discharge and ground circuits prior to touching them.

DO NOT SERVICE OR ADJUST ALONE:

Under no circumstances should any person reach within or enter the enclosure of (for the purpose of servicing or adjusting) the equipment without immediate presence or assistance of another person capable of rendering aid.

DO NOT TAMPER WITH INTERLOCKS:

Do not depend upon door switches or interlocks for protection but always shut down motor generators or other equipment. Under no circumstances should any access gate, door, or safety interlock switch be removed, short-circuited, or tampered with in any way (other than for replacement) without the specific authority of the Bureau of Ships. Personnel must not rely upon the interlock switches to remove dangerous voltages from the equipment. Periodic tests and inspections must be made on these devices to ensure that they are operating correctly.

RULES REGARDING CIRCUITS EMPLOYING 300 VOLTS OR MORE:

Voltages in excess of 300 volts shall not be measured by probing or holding the test probe in the hands. Whenever measurements are necessary on equipment employing potentials in excess of 300 volts or where rubber gloves cannot be worn, the following precautions and procedures shall be observed:

The equipment shall first be de-energized.

High-voltage capacitors shall be discharged with a suitably insulated shorting- or grounding-bar.

The technician shall ascertain that test equipment controls are set correctly for testing high voltage.

Test leads capable of carrying high voltage shall be secured on the desired test point by the technician.

The technician shall withdraw his hands from the equipment under test, making sure that he is also free from leads and in a good position for making correct meter readings.

The equipment shall be energized by an assistant standing by the switch.

After the necessary reading is made, the equipment shall be de-energized and high voltage capacitors shall be discharged.

The foregoing steps shall be repeated as necessary for each measurement.

GENERAL NOTES (WHICH CAN SAVE YOUR LIFE):

Make certain that you are not grounded whenever you are adjusting equipment or using measuring equipment.

In general, use only one hand when servicing live equipment.

If test meter must be held or adjusted while voltage is applied, ground the case of the meter before starting measurement, and do not touch the live equipment while you are holding the meter. Some moving vane type meters should not be grounded; thus they should not be held during measurements.

Do not forget that high voltages may be present across terminals that are nominally low voltage due to equipment malfunction or breakdown. Be careful even when measuring low voltages.

Do not use test equipment known to be in poor condition.

High-voltage, high-capacity capacitors should be discharged with an insulated shorting- or grounding-bar with approximately 10 ohms in series with the grounded line.

Where neither terminal of a capacitor is grounded, short the capacitor terminals together.

Take time to be safe.

RESUSCITATION

An approved poster illustrating the rules for resuscitation by the Holger-Neilsen method shall be displayed prominently in each radio, radar, or sonar enclosure. Posters may be obtained by request to the Bureau of Medicine and Surgery.

Another effective means of administering artificial respiration is the mouth-to-mouth resuscitation method. Familiarization with this method is important particularly if the victim has above the waist injuries-broken bones, burns, etc. —or if the space is to confining for the Holger-Neilsen method. The following procedure and cautions will serve as a guide for using the mouth-to-mouth resuscitation method.

1. Clear the mouth of foreign objects with the middle finger of one hand. With the same finger, press the tongue forward.

2. Place victim in a face-down, head-down position, and pat firmly on the back with free hand. This should dislodge any foreign objects in the air passage.

3. Place victim on back, and use middle fingers to literally lift lower jaw so that it "juts out." This is accomplished by placing fingers beneath jaw bone and behind it on a line almost perpendicular to ear. Using one hand, hold jaw in this position.

4. Use thumb and first finger to close nostrils by reaching over forehead to grasp nose of victim, making leakproof seal.

5. Place your mouth over the victim's mouth, making a relatively leak-proof seal.

6. Breathe into victim's mouth with a smooth steady action until you observe chest rise.

7. When lungs are inflated, remove your lips from victim's mouth and allow lungs to empty. Repeat this cycle every 5 seconds.

8. If at any time resistance to breathing is detected and victim's chest does not rise, place victim in face-down head-down position and pat firmly on back, then quickly resume mouth-to-mouth resuscitation.

Points To Remember

Aspects of concern when placing victim in resuscitation position or in interim between cycles:

1. Body should be inclined slightly in such a way that fluid drains better from respiratory passage.
2. The head should be extended (not flexed) forward and chin should not sag. Obstruction of respiratory passage may occur if this is not done.
3. Check that tongue or foreign matter is not obstructing air passage.
4. A smooth rhythmetical cycle is important; split-second timing is not essential.
5. Once respiration has been restored, keep victim warm and absolutely quiet. Do not permit victim to sit or stand up.

TOPIC 1: INTRODUCTION TO TEST EQUIPMENT

Your Progress up to Now

You have performed numerous experiments and performance tests in the Fire Control Radar Special Circuits and earlier courses. You used voltmeters, ohm-meters and ammeters to measure values of AC and DC voltages, resistances and current, and the oscilloscope to observe and check waveforms. You have checked frequency using an audio signal generator as a reference.

When you used these test equipments it was assumed they were performing properly with correct calibration. Since this is not always the true situation, you, as the Fire Control Technician must be able to recognize faulty performance of test equipment and take corrective action where practical.

Your goal is to learn the theory of operation and acquire skill in operating the following test equipments:

Multimeter or Volt-Ohm-Milliammeter (VOM)
Vacuum Tube Voltmeter (VTVM)
Capacitance Bridge ZM 11/U
Special Test Probes
Oscilloscope (general purpose)
Synchroscope (AN/USM-32)
Synchroscope (AN/USM-117)
Oscilloscope (Tektronix 545A)

Fire Control Technician training has given you some practice in the use of test equipment such as the multimeter, oscilloscope and audio signal generator. You may have been slightly confused at times because voltage readings on the multimeter were not of the value expected and some of the waveforms observed showed unexpected distortion. These may have been due to the loading effects of the meter or oscilloscope on the circuit being tested. In the next topics you will learn about the loading effect of meters and the distortion of scope presentations and how they are eliminated by using vacuum tube voltmeters and special test probes.

In performing the following experiments, you will see the loading effects of various test equipment on the circuits you studied in Radar Special Circuits. You will learn how to determine frequency, make phase comparisons and measure voltages using oscilloscopes. You will learn to interpret Lissajous patterns and how to calibrate and use several of the more complicated precision oscilloscopes and synchroscopes. You will learn to use a precision R-C-L tester.

Aboard ship, in your rating, you will be assigned to help maintain and operate a particular equipment of a missile or gun fire control system. It may be a fire control radar, a weapons direction system, or a computer. These equipments, part of the ship's weapon system, must be kept in "top notch" operating condition at all times. To do this you must know the equipment, the checks of it's performance, and how to locate and repair the casualties that occur. Test equipments are the "tools of your trade". You must know how to use them to check and

Your Progress up to Now (Continued)

repair the equipments of your assigned system. If it is necessary to take time to study the test equipment and its set up before troubleshooting, it will result in distraction from casualty analysis and increased "down time" of the system.

The knowledge and skill gained from performing the following experiments will help prepare you for your assigned task aboard ship.

TOPIC 2: MULTIMETER (VOM) AND VACUUM TUBE VOLTMETER

Volt-Ohm-Milliammeter (VOM)

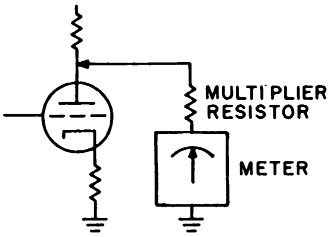
The VOMs in general use in the Navy are of the multi-function, multi-range type. Multi-function means that they are designed to read AC or DC Voltage, Direct Current and DC Resistance. Multi-range means that these quantities can be measured in different ranges or scales, allowing for more accuracy and broader application.

Since there are many different types of these meters presently in use, this discussion will cover a VOM's general description.

Some VOMs have only one main rotary switch which is used to change both the function and range scale of the meter. More commonly found, will be the type with two main rotary switches, one for setting the function and the other for selecting the range. In addition you will normally find; a ZERO ADJUST CONTROL for zeroing the meter; banana jacks or phone tip jacks for plugging in test leads.

The face of the meter usually has a scale available for each setting of the function and range switches. A short study of the scales should be sufficient to determine how they will be used. Care should always be taken so that readings are from the proper scale.

One of the most important features to look for in a VOM is it's sensitivity. By this is meant, how accurate it's voltage readings will be on various scales. You may have heard one of your instructors refer to a meter as a 20,000 ohm per volt meter. What does this mean? Let us recall from our study of basic electricity how a voltmeter is hooked up internally. You may remember that it consists of a multiplier resistor and a meter movement in series. Whenever a voltage is to be measured, this circuit is paralleled with the circuit whose voltage is to be read, as shown below. This parallel hook-up will decrease the total resistance of the circuit somewhat. If the internal resistance of the meter is very high, the effect on the circuit is negligible. However, if the internal resistance of the meter is low, it will "load down" the circuit and the reading will not be accurate.

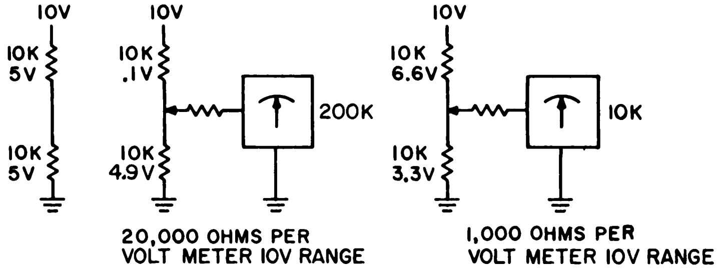


1.—Basic VOM.

A 20,000 ohms per volt meter will have a meter movement and multiplier resistor with 20,000 ohms of resistance for each volt on the range it is set on. For instance, when it is set on the 10 volt range, it will have 10 x 20,000 or a total internal resistance of 200 K ohms. A 1000 ohms per volt meter has an internal resistance of only 10 K ohms

Volt-Ohm-Milliammeter (VOM) (Continued)

when set on the same range, (10 x 1,000 ohms). It is shown below how these two meters would affect the same circuit. The 20 K ohms per volt meter would affect the circuit very little and its reading would be accurate. Whereas, the reading on the 1,000 ohms per volt meter would be very inaccurate, even in this low impedance circuit. Therefore the higher the ohms per volt rating of the meter, the more accurate the voltage readings will be.



2.—VOM Circuit Loading Effects.

A VOM uses battery power for resistance readings. In some meters a low voltage battery will be employed when the meter is set on the low resistance ranges and a slightly higher voltage battery is employed when, the meter is set on the high resistance ranges. On most meters, there is only one resistance scale. The resistance is then found by multiplying the scale reading times the multiplication factor at the range switch settings.

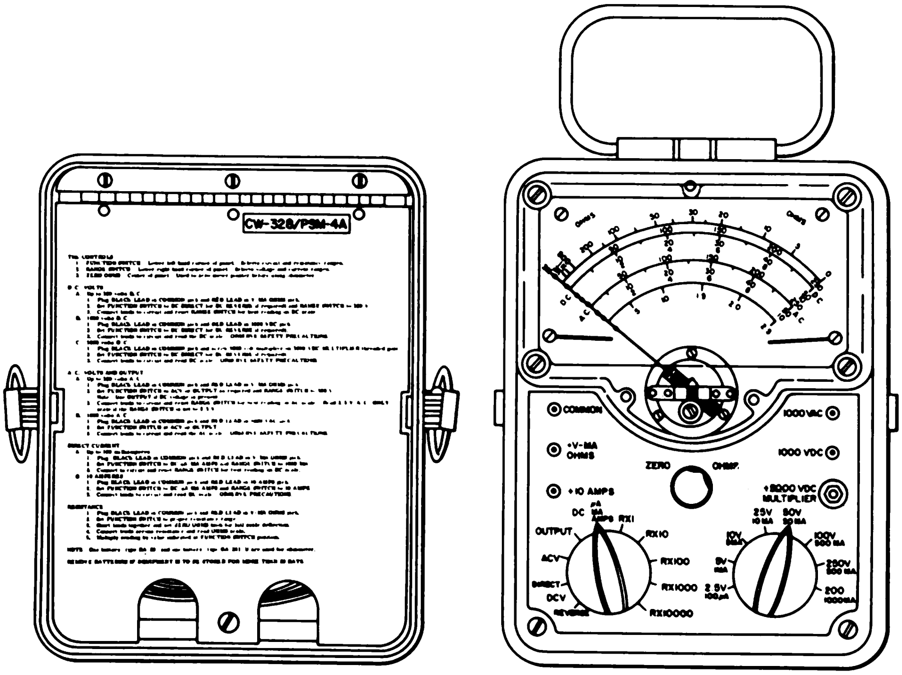
> CAUTION: Since resistance readings are taken using a low voltage battery as a power source, the series resistance of the meter is necessarily low. Never place the meter across an energized circuit when the function switch is set for resistance. To do so will result in serious damage to the meter, since the low series resistance can not limit current to a safe value. The low value precision series resistor and/or the meter movement will burn out and the meter needle may be bent by hitting the peg. This is by far the most common cause of meter failure. Always check for voltage before taking resistance readings on a circuit. Upon completion of resistance readings, secure the meter on the highest AC range.

The "OUTPUT" function blocks DC, allowing measurement of signal voltages without the DC component. The AC scale will measure the effective voltage, both the AC signal and the DC level on which it is superimposed.

The major disadvantages of the VOM are the loading effect of the low range scales when used to measure voltage across high impedance circuits, and the varying accuracy at different frequencies on AC or OUTPUT functions.

Volt-Ohm-Milliammeter (VOM) (Continued)

In summation it can be said that the VOM is a very handy, versatile, and useable unit of test equipment. It can be used for AC, DC, and OUTPUT voltage, DC current, and resistance measurements. It is small and easy to move about, and requires no external power source. This makes it especially useful aboard ship.



3.—Multimeter AN/PSM-4A, Front View with Cover Open.

General Instructions for Using VOM

1. Always check meter setting carefully before taking a reading.

2. Always start at the highest range practical to prevent "pegging" the needle.

3. Check the meter for zeroing.

4. When reading resistance, check zeroing each time range is changed.

5. When taking DC readings, if polarity is unknown, touch probes to circuit under test to check for proper deflection of the needle with range set to the highest scale.

6. Always take readings looking straight into the meter, not at an angle. This will eliminate parallax.

General Instructions for Using VOM (Continued)

7. For final readings use the range that gives the reading nearest to center scale for best accuracy.

8. Never leave the meter on a resistance range when not in use. To do so may drain the batteries.

Vacuum Tube Voltmeter (VTVM)

One of the most helpful developments in meter type measuring devices for testing electronic equipment is the incorporation of the vacuum-tube in the measuring instrument itself. The basic meter movement (ordinarily the moving-coil, permanent-magnet meter) is connected into a vacuum-tube circuit in such a way as to indicate voltage, current, and resistance. The vacuum-tube voltmeter, abbreviated VTVM, achieves its main advantage over the ordinary meter because it isolates the meter from the circuit under test; and, by utilizing the vacuum tube's capabilities as an amplifier or rectifier, greatly increases the sensitivity of the measuring system beyond that established by the meter itself. Moreover, it extends the frequency range of the meter indicator far up into the hundreds of kilocycles region. (Note: Special probes may extend frequency limits to 100 megacycles.) Finally, it minimizes the loading effect of the measuring device on the circuit under test.

Another advantage of the VTVM is that the input impedance is high and constant for all DC voltage ranges; in contrast to the impedance of the ordinary multi-range voltmeter which varies according to the full scale voltage range being used.

Most VTVMs have an input resistance of about 11 megohms; laboratory types go much higher. But even in the 11-megohm units this is equivalent to the input resistance of a 20, 000 ohms-per-volt meter with a full-scale range of 550v. However, it is on the low-voltage ranges that the advantage of the VTVM is most apparent. For example, a typical 20, 000 ohms-per-volt meter has an input resistance of only 0. 2 megohms on the 10-v scale; the constant 11-megohm resistance of the VTVM on this scale is 55 times as high. Therefore, we can say that for low voltage measurements where sensitivity is important, the VTVM is by far the most useful type of meter. At high voltages, 500 volts DC and higher, the 20, 000 ohms-per-volt instrument is just as useful as the vacuum-tube voltmeter. This must be said for the 100, 000 ohms-per-volt meter too, which presents a meter resistance higher than the usual VTVM at voltages as low as 150 volts DC.

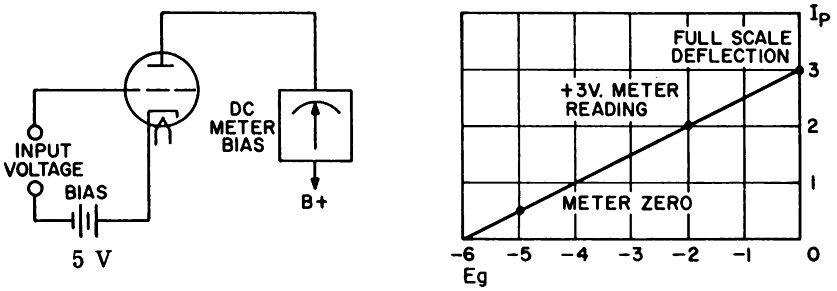
The Basic DC VTVM

The direct-current VTVM is, in the main, an amplifying triode tube used in such a manner that the DC voltage to be measured causes a change in its plate current. This current is indicated on a moving-coil meter. The voltage to be measured is applied to the control grid circuit of the vacuum tube; it offsets the operating bias and so changes the plate

The Basic DC VTVM (Continued)

current to above or below the no-input-voltage value. When the plate current meter is suitably calibrated, it's indications are interpretable directly in values of applied input DC voltage.

The basic arrangement shown below symbolizes the conditions of operation described by the grid voltage-vs-plate current characteristic. Assume that a fixed negative bias causes plate current to approach cutoff with zero input (a small current flows when meter is zeroed). Voltage applied to the input terminals will offset the bias and cause plate current to increase. According to the tube characteristics shown below, a positive input voltage of 3 volts applied to the grid will decrease Eg to -2 volts and increase Ip from .4 ma to 2 ma. A maximum input voltage of 5 volts will increase plate current to 3 ma which will give full scale deflection of the meter needle.

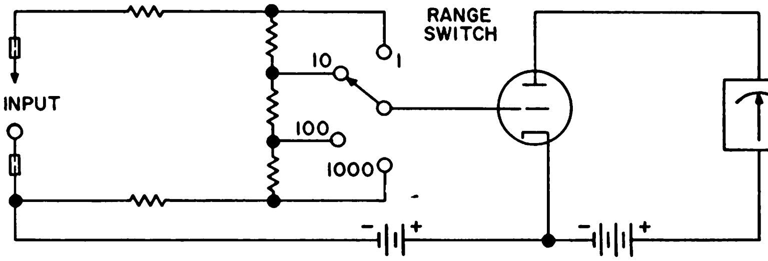


4.—(A) Basic VTVM (B) Tube Characteristics.

The relationship between input voltage and the plate current change enables calibration of the plate current meter in terms of the voltage applied to the input. Thus, instead of calibrating the plate meter in current from 0 to 3 ma, it can be calibrated in voltage from 0 to 5 volts full scale and becomes direct reading. Because the grid voltage-plate current characteristic is substantially linear (within limits normally used) the meter scale is linear.

The limit of DC voltage which may be applied to the vacuum-tube input circuit is determined by the operating negative grid bias, because freedom from grid current is essential. However, it is readily evident that a meter of this type can neither be restricted in its measuring capabilities to a single range, nor to as low a value as 5 volts. The answers to both limitations are found in the use of a voltage divider across the grid circuit as shown on the adjacent page.

The Basic DC VTVM (Continued)



5.—DC VTVM Circuit.

By making the divider resistance very high, say 10 megohms or higher, the input impedance of the instrument is made high. When the taps along the divider are arranged in a suitable manner, a wide range of DC voltages can be measured, and the maximum voltage applied to the grid circuit remains 5 volts for full scale deflection on the meter for every range.

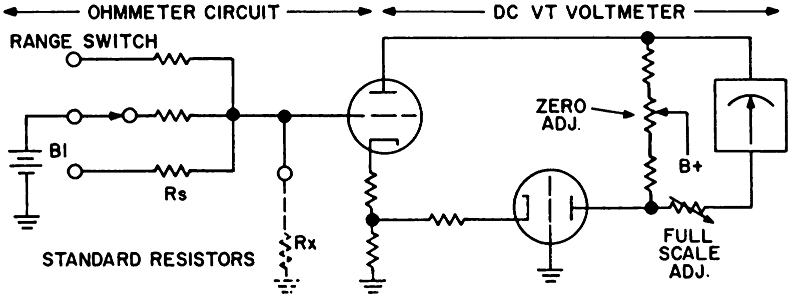
Each tap on the divider affords a certain voltage ratio between the voltage applied across the divider and the voltage applied to the tube. Each tap along the divider represents a voltage range, to be used with its own scale on the meter or as a multiplying factor, as determined by the design of the instrument. The taps on the divider are arranged in decade steps of 1, 10, 100, and 1,000; these figures serve as multiplying factors. If the lowest full-scale range is 5 volts, the maximum voltage measurable with the device is 5,000 volts when the divider is set to the 1,000 position.

It is interesting to note that if the total divider resistance is 10 megohms, input impedance remains constant for the full range of the instrument, for all scales. Changing the voltage-divider ratio by moving the range switch does not change the total resistance of the divider.

The VTVM used for measurement of an AC voltage involves a number of considerations, in addition to those encountered in the DC VTVM. Finished instruments allow the measurement of both AC and DC quantities, but AC involves rectification, whereas DC does not. Thus, while a single VTVM may provide these two measuring capabilities, the AC measurements stem from a somewhat more complicated circuit arrangement. The AC input section of a VTVM must incorporate some means of rectification, usually a diode. After the AC has been rectified it can be applied through switching arrangements in much the same manner as the DC and the meter scale calibrated to read AC (RMS).

Direct-Reading V-T Ohmmeter

By addition of the circuit shown in the left-hand portion below almost any type of DC VTVM is converted into an ohmmeter. The VTVM shown in the right-hand portion of the figure is a symbolized balanced circuit. Before Rx, the unknown resistance, is placed in the circuit the full-scale adjustment is made. In this condition, the full bias voltage of B1 is applied to the grid of the upper triode through one of the standard resistors, Rs. If Rx is now inserted in the circuit, Rs and Rx form a voltage divider across B1, and only the voltage drop across Rx is applied to the upper triode. The meter will then indicate something less than full scale, the amount being directly proportional to the decreased bias on the grid of the upper triode, and of course directly proportional to the resistance of Rx. The scale can then be calibrated in terms of the resistance of Rx. Remember that before a reading is taken this ohmmeter is adjusted for full scale without Rx in the circuit, thus signifying an infinite resistance. (Note: This scale is the reverse of the VOM resistance scale.)



6. —VTVM Ohmmeter Circuit.

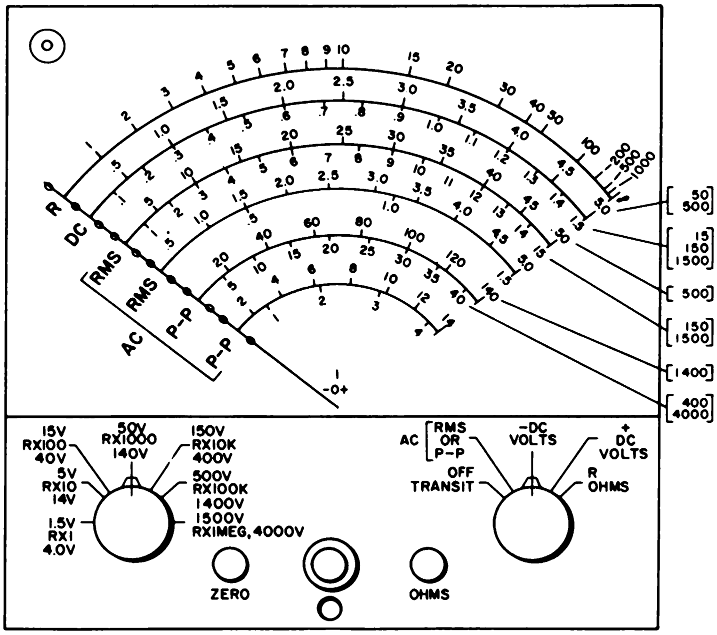
In the VTVMs that you will use, the AC, DC, and resistance circuits are all incorporated into one compact instrument. Switches are provided for changing functions and ranges similar to the switches on the VOM. In general, the operation of the two instruments is the same except that the VTVM must normally have an AC power source available, although there are some few models that use battery power. This power requirement is the major disadvantage of the VTVM. It's high sensitivity on the low ranges is it's biggest advantage over the VOM.

Some VTVM's have special probes that may be used with the meter. These probes will be discussed in a later topic.

Direct-Reading V-T Ohmmeter (Continued)

RANGE	INPUT RESISTANCE		CIRCUIT LOADING EFFECT
	VTVM	Non-Elec. *	
5V	10 meg	0. 1 meg	Non-Electronic Voltmeter 100 times that of VTVM
10V	10 meg	0. 2 meg	Non-Electronic Voltmeter 50 times that of VTVM
50V	10 meg	1 meg	Non-Electronic Voltmeter 10 times that of VTVM
100V	10 meg	2 meg	Non-Electronic Voltmeter 5 times that of VTVM
500V	10 meg	10 meg	Non-Electronic Voltmeter same as VTVM
1000V	10 meg	20 meg	Non-Electronic Voltmeter one-half that of VTVM

*Non-Electronic Voltmeters (20, 000 ohms-per-volt)



7. —Senior Voltohmyst WV-98A Panel.

MULTIMETER (VOM) AND VACUUM TUBE VOLTMETER

Experiment 2-1—Comparing VOM and VTVM Affect on the Overdriven Amplifier

In this experiment you will compare the effect of a VOM and a VTVM on the overdriven amplifier circuit of the chassis.

With the circuit in a proper operating condition (square wave on the scope from plate pin 5 (A-11L) V3B) measure the voltage at grid pin 1 (A-10L) of V3A with a VOM on the 10 volt scale and observe the effect this has on the square wave presentation on the scope. There should be only a slight change. Next measure the same voltage with a VTVM and observe the presentation. There should be no change. Comparing the effect of the two meters you will find that, even though the VOM had some effect, it did not seriously affect the operation of this circuit. Therefore either meter could be used for taking measurements at this point.

WARNING

> Do not reverse the test leads when measuring high voltages of different polarities. Use POLARITY REVERSE switch on the electronic voltmeter. Contact between the voltmeter case and ground may cause severe shock, if the above caution is not observed.

Experiment 2-2—Comparing the Effect of a VOM and a VTVM on the Cathode Follower Circuit

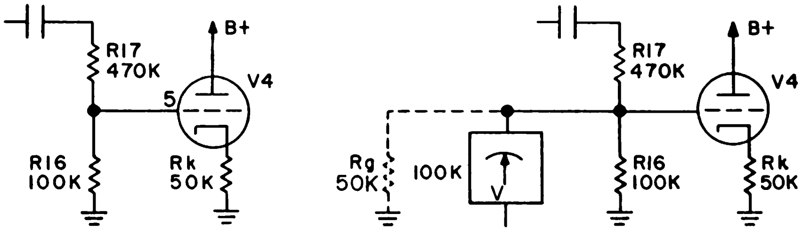
In this experiment you will compare the effect of the VOM and the VTVM on the cathode follower circuit. Refer to NP 92213A Vol. 1, pages 62 and 63.

Connect the scope vertical input probe to the cathode pin 8 (A-19L) of V4 and adjust for a square wave presentation. Connect the VOM and VTVM negative leads to ground. Set both meters on the negative DC 5 volts scale. Touch the positive lead of the VOM to grid pin 5 (A-17L) of V4 and observe the effect this has on the scope presentation. It should decrease to about one half of it's original amplitude. Next touch the VTVM positive lead to the same point and observe the waveform. There should be no apparent effect; the difference in the effects of the VOM and VTVM in this circuit is so pronounced that it would be well to analyze the circuit to determine the reason.

Experiment 2-2—Comparing the Effect of a VOM and a VTVM on the Cathode Follower Circuit (Continued)

Below, (A) shows the input circuit for the cathode follower. The signal from the plate of V3B is being developed across the voltage divider network R16 and R17. The voltage applied to the grid is the voltage developed from grid to ground across the 100K resistor R16 and is therefore, determined by the ratio of R-16 to total resistance or 1:5.7. Below, (B) shows the same circuit with the addition of the VOM. Since the VOM on the 5 volt scale has an internal resistance of 100K (5 x 20,000), Rg from the grid to ground has decreased to 50K. The ratio of Rg to Rt is now 1:10.4. Therefore, more of the signal will be dropped across R17 and less across the circuit from grid to ground. When the VTVM is connected into this circuit, it's internal resistance is so high (11 megohms in most VTVMs) that it's effect on the total resistance from grid to ground is negligible. Therefore, the signal applied to the grid will be affected so little that is unnoticeable with most test equipment.

Next set both meters on the positive 25 volt DC scale and check the voltage from cathode pin 8 (A-19L) to ground while you observe the effect on the scope. In this case, the input impedance of both meters is much higher (VOM 500K-VTVM 11 MEGOHMS), than the circuit impedance at this point (about 4.7K), therefore, neither meter will affect the circuit noticeably.



(A) (B)

8.—VOM Effects.

Experiment 2-3—Comparing the Effects of the VOM and VTVM on Differentiating Circuit

In this experiment you will compare the effects of the VOM and the VTVM on the differentiating circuit C9 and R19 at different settings of the potentiometer R19. This experiment will be done in conjunction with the experiment on page 86 NAVPERS 92213A Vol. 1.

Experiment 2-3—Comparing the Effects of the VOM and VTVM on Differentiating Circuit (Continued)

Set both meters on the 5 volt DC scale and connect the negative leads to ground. With R19 set at 125K and the circuit in operation, touch the positive lead of the VOM to the top of R19 (A-20L) and observe the effect on the waveform presentation on the scope. There should be considerable change in the waveform in both amplitude and the amount of differentiation. By this time you should be able to analyze the circuit involved and explain the reason for the occurrence. Next touch the positive lead of the VTVM to the top of R19 (A-20L) and observe the results on the scope. There should be no change.

With R19 set on 50K, repeat the experiment with both meters. The VOM should have somewhat less effect here than it did with R19 set at 125K, due to the lower circuit impedance. The VTVM will still have no effect.

It should be evident from this experiment that placing a VOM on the 5 volt DC scale across the differentiated output could seriously affect the circuits that are being triggered by this output since both the amplitude and the width of the spike are affected.

Experiment 2-4—Comparing the Effects of VOM and VTVM on Limiting Circuit

In this experiment you will see how a VOM, used under certain conditions, can give a false impression of a casualty. This experiment will be done in conjunction with the experiment on page 103, NAVPERS 92213A, Vol. 1.

For this experiment set up the V5 circuit as a series negative limiter. Connect the scope's vertical probe to the cathode pin 8 (A-21L) limiter. Observe that the negative portion of the waveform is being limited. Note the amplitude of the waveform.

De-energize the chassis and unsolder the ground end of R20 (A-21R). This opens the circuit and there should be no output. Apply power to the chassis and observe the waveform on the scope. With the scope connected across this open circuit you should observe very small negative and positive spikes.

With the positive lead of the VOM connected to the cathode pin 8 (A-21L) and the negative lead connected to ground, select the DC voltage scale which presents a meter reading closest to, but does not exceed, full scale deflection. The meter will measure approximately 5 VDC. When selecting the proper DC voltage scale on the meter start with higher scales and select lower scale when it is known to be safe for the meter. Observe the waveform on the scope. The amplitude and limiting action should be the same as it was with R20 connected into the circuit, since the internal resistance of the meter on the 5 volt scale is the same value as R20 or 100K. From all indications, the circuit seems to be operating properly except that the VOM reads a slight amount higher than normal.

Experiment 2-4—Comparing the Effects of VOM and VTVM on Limiting Circuit (Continued)

In reality, R20 is open and we have a signal due to the insertion of the VOM into the circuit. Next place a VTVM on the 5V scale between pin 8 of V5 and ground and observe the effect on the presentation on the scope.

It can be seen from this experiment that the unskilled technician, unaware of the VOM's limitations could easily run into difficulty in trying to diagnose this type of casualty.

De-energize the chassis and resolder the ground end of R20 to it's terminal (A-21R).

Experiment 2-5—Comparing VOM and VTVM Effect on Frequency Stability of Blocking Oscillators

In this experiment you will determine the effects of the VOM and the VTVM on the frequency stability of the FREE RUNNING and the TRIGGERED BLOCKING OSCILLATOR. This experiment will be done in conjunction with the experiment on pages 126 and 127 NAVPERS 92213A, Vol. 1.

When you have completed the experiment of page 126, and while you still have the closed loop pattern, proceed as follows: Hook both VOM and VTVM negative leads to ground. Set both meters on the 50 volt DC scale and take readings at the grid, pin 4, and cathode, pin 6, of V6B while observing the results on the scope. (CAUTION: Set the meters on DC when reading grid voltage.) You will notice that each meter has a decided loading effect on the Free Running Blocking Oscillator although the VOM's effect will be more pronounced. The loading effect in each case changed the frequency of operation of the Blocking Oscillator. Record these findings for future reference and proceed with the experiment on page 127.

After you have completed step 5 in the experiment on Triggered Blocking Oscillators, page 127, proceed as follows: Connect the VOM and VTVM as before and take readings at the grid, pin 4, and cathode, pin 6, of V6B while observing the result on the scope. Compare these results with the results of your previously recorded readings. In this case you should find that neither meter will have any effect on the frequency of the Blocking Oscillator. This is as it should be since the Blocking Oscillator is being triggered by the output of the Wien Bridge Oscillator. Therefore, as long as the Wien Bridge Oscillator's frequency remains stable, the Blocking Oscillator output will remain stable.

As a final check, switch the VOM to the -5 volt DC scale and touch the positive lead to the grid pin 1 of V2, the Wien Bridge Oscillator, and observe the result on your scope. As you remember from your first experiment, this caused the Wien Bridge Oscillator to become unstable. Therefore, the Blocking Oscillator will also become unstable.

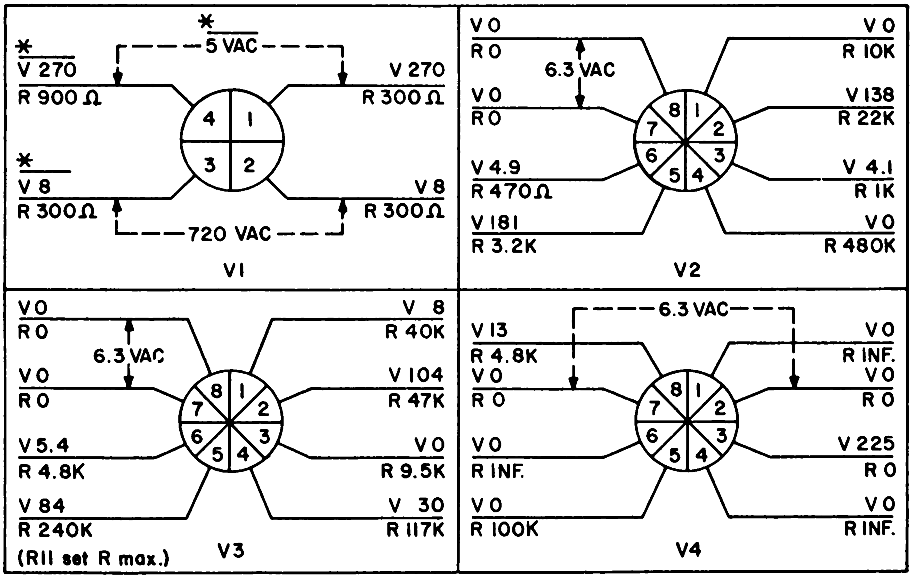
Experiment 2-6—Voltage and Resistance Measurement

When troubleshooting vacuum tube circuits, best results are attained by following certain definite steps. They are (1) isolating the trouble to the defective stage by signal tracing, (2) tube checking, (3) voltage checking tube pins to determine defective circuit, and (4) resistance checking defective circuit to isolate defective components.

In order to check for proper voltage and resistance, references are needed. These are voltage and resistance diagrams provided in NAVWEPS OPs for equipments. The voltage and resistance diagrams show a drawing of each tube socket, the voltage and resistance of each socket pin. These values are taken under set conditions and these conditions under which the readings are to be taken are listed on the diagram.

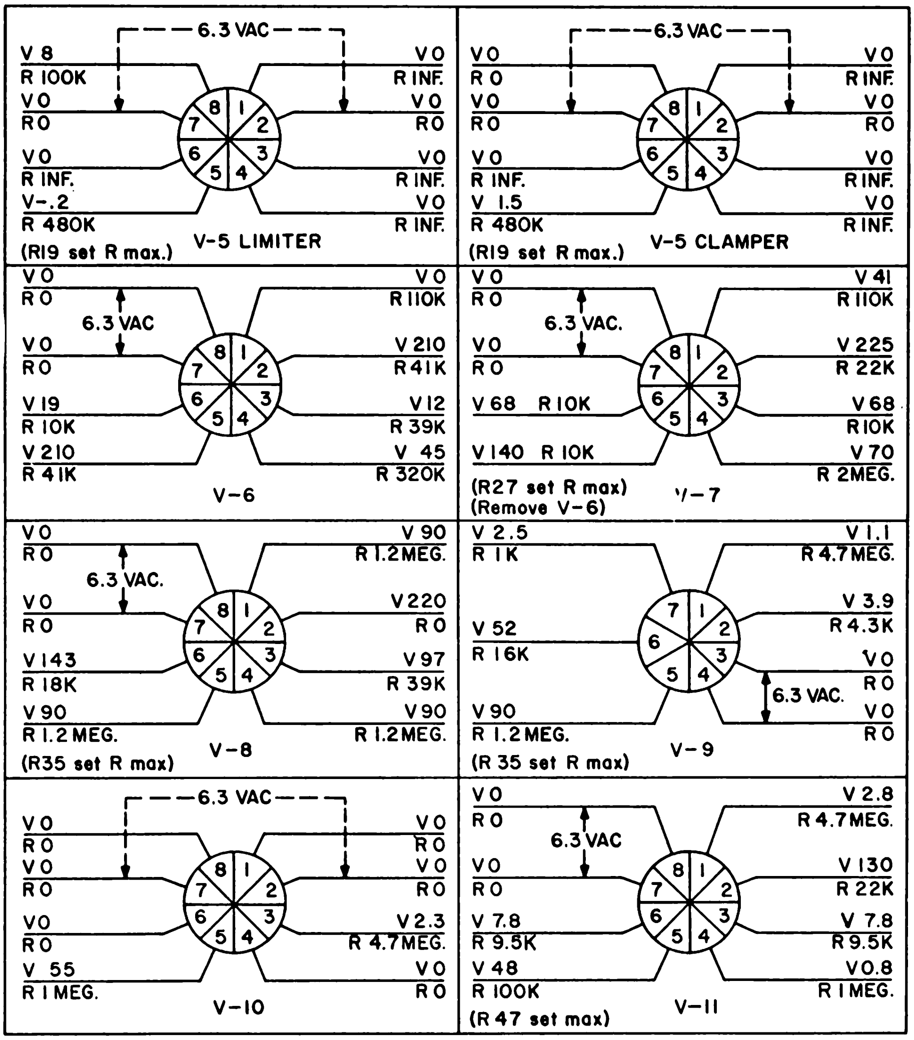
Following is a voltage and resistance chart of your Fire Control Radar Special Circuits Chassis. Take two readings on your chassis and compare them to the readings on the chart. (Read the notes on the voltage and resistance diagram before taking readings.)

Some variation is allowed due to the tolerance of the components and variations in the power supply output.



9.—Chassis Voltage and Resistance Diagram.

Experiment 2-6—Voltage and Resistance Measurement (Continued)



10.—Chassis Voltage and Resistance Diagram.

NOTES:

1. Voltages DC to ground unless otherwise stated.
2. Voltages read with a 20,000 ohms-per-volt meter.
3. Voltages read with circuit in operation.
4. Resistance read with potentiometers set at maximum resistance, B+ terminal grounded and power off.

Review

In this topic you learned about multimeters and vacuum tube voltmeters. Both are in wide use for circuit measurements of voltage and resistance. The multimeter is also used for current measurement.

The multimeter is extremely handy since it is easily portable, requiring no external power source and is highly accurate in most cases. The AN/PSM-4 series, in wide use throughout the Navy has a 50 u amp meter movement and a 20, 000 ohms per volt sensitivity on the DC ranges. The main disadvantage of the multimeter is that current must be drawn from the circuit under test to operate the meter movement. This results in circuit loading when the lower ranges are used to measure voltages of high impedance circuits. The accuracy of the multimeter is affected by frequency on AC and OUTPUT scales.

The VTVM has a constant high impedance input for all ranges, resulting in negligible circuit loading. Most VTVMs require an external power source but a few use batteries. This source supplies current for the meter movement, the circuit under test need only supply a voltage to the control grid of the VTVM amplifier tube. The VTVM is supplied with a high impedance probe and shielded test lead which, with the high input impedance of the meter, make it suitable for accurate voltage measurements on nearly any circuit within its designed range of voltage and frequency.

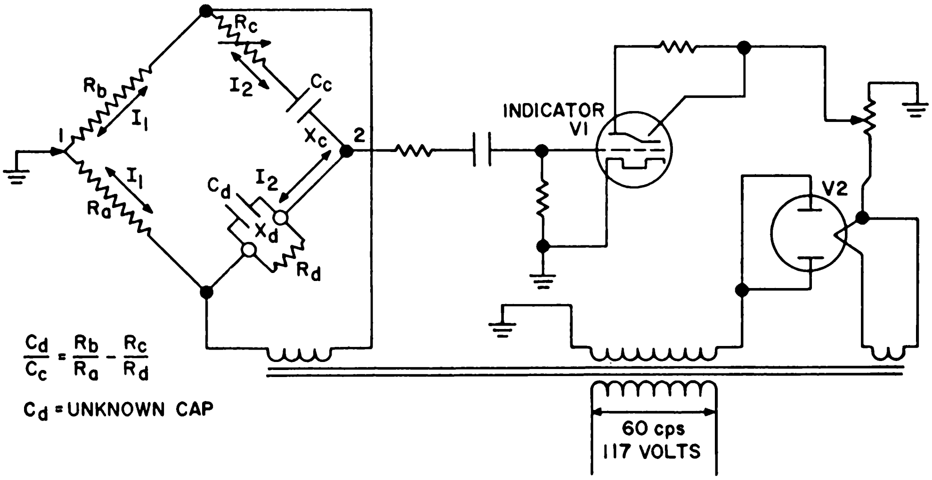
TOPIC 3: CAPACITANCE, INDUCTANCE, AND RESISTANCE BRIDGE ZM11/U

The ZM11/U is a precision test instrument for shipboard use. It is used to measure capacitance, inductance, resistance, transformer turns ratio, dissipation factor of inductors and capacitors, and leakage in electrolytic capacitors.

You will use the ZM11/U to measure resistance and capacitance in the experiments to follow. You will attain skill in its operation and knowledge of its usage.

Some Fire Control electronic equipment contain circuits having precision resistors and capacitors with extremely close tolerance. These circuits usually have very critical output characteristics for proper operation. The ZM11/U can be used to check these circuit components accurately.

Capacitance, inductance, and resistance are measured for precision accuracy by means of alternating current bridges which are composed of capacitors, inductors, and resistors in a wide variety of combinations. These bridges operate on the same principle as the Wheatstone Bridge (Resistance Bridge) in which an unknown resistance is calculated in terms of the known resistance after the bridge has been balanced. Below is shown a simplified capacitance bridge circuit.



11.—Simplified Schematic of Capacity Checker.

When the bridge is balanced by adjustment of two variable resistors (dials indicate capacitance) there is no AC voltage developed across the input of indicator tube (V1), and it's shadow angle is maximum. Any slight unbalance produces an AC voltage which in turn develops a grid leak bias and lowers the Ip of V1, thus reducing the shadow angle.

CAPACITANCE, INDUCTANCE, AND RESISTANCE BRIDGE ZM11/U

Capacitors may be checked either in the circuit or disconnected from the circuit. Electrolytic capacitors may be polarized and charged to the rated voltage to check for leakage current. Complete instructions are contained in Instruction Book, NAVSHIPS 91704.

When using normal troubleshooting methods, a suspected open capacitor can be checked by touching a known good capacitor across it's terminals. A shorted capacitor can easily be found with an ohmmeter. The advantage of the ZM11/U is it's ability to check marginal components, ones that have changed values but are not open or shorted. For instance a capacitor that has changed in value is very difficult to find by normal methods, yet it is often impractical to replace all suspected capacitors in the circuit. This is only one case in which the ZM11/U can be used to good advantage.

Experiment 3-1—Checking Resistors and Capacitors of Differentiating Circuit Using a ZM11/U

In this experiment you will have an opportunity to gain experience using the ZM11/U and learn a few of the test functions it is able to perform. Before beginning the experiment, remove the cover from the ZM11/U and locate the following switches and dials you will use in this experiment.

1. FUNCTION Switch-upper left.
2. RANGE Switch-upper left.
3. BALANCE-Indicator-center left.
4. MULTIPLY RANGE by Dial-lower center.
5. PANEL METER-upper center.
6. VOLTAGE CONTROL-upper right.
7. OSCILLATOR ADJUST-to right of Panel Meter.
8. OSCILLATOR Switch-right center.
9. POWER-ON-OFF-lower right.
10. PILOT Lamp-left of Power-On-Off.
11. D DIAL-lower left.

Measuring Resistance

The ZM11/U is capable of measuring resistors from 1 ohm to 11 megohms. Each man will have the opportunity to check several resistors.

Experiment 3-1—Checking Resistors and Capacitors of Differentiating Circuit Using a ZM11/U (Continued)

For resistance measurement, the FUNCTION switch is set on R. Select a suitable range setting with the RANGE switch, reading from the R ring of the scale. Plug the meter in and switch the POWER switch to ON. The PILOT lamp should light up and after a few minutes warm up time, the BALANCE indicator should glow a light green. Connect the unknown resistor to the R posts, second and fourth from the left at the top of the meter. Adjust the MULTIPLY BY dial until the BALANCE indicator pattern shows the maximum possible opening in the eye, indicating balance. Multiply the RANGE switch setting by the MULTIPLY BY dial reading and you have the resistance of the resistor. Check several resistors in this manner.

Measuring Capacitance

The ZM11/U is capable of measuring capacitances from 10 uuf to 1100 uf. You will need several different size capacitors to perform this experiment. Set up the meter in the following manner. Turn the FUNCTION switch to C. Select a suitable range for the capacitor under test with the RANGE switch, reading on the C scale. Energize the meter and allow warm up time (BALANCE indicator lights up). Connect the unknown capacitor between the C posts, third and fourth from the left. Attempt a balance (maximum opening of eye of the BALANCE indicator) by adjusting the MULTIPLY BY dial, perfecting it by simultaneous adjustment of the D dial. When balance is complete, multiply the MULTIPLY BY dial reading by the RANGE switch setting to obtain the capacitance. Perform this experiment with several capacitors.

Experiments 3-2—Capacitor Quality Tests

The following tests determine the condition of a capacitor without removing it from the circuit or chassis. The equipment under test must be de-energized, however. In general, the tests will determine whether a capacitor is open or shorted. In this experiment you will check the condition of C9, the capacitor in the differentiating network. Refer to NAVPERS 92213A Vol. 1, page 84 for test set-up.

To start the test, de-energize training chassis, remove the coaxial cable from the lid and plug it into the QUALITY TEST jack at the right. Place the cable to one side and make sure the clips are not touching.

To test for an OPEN, set up the meter as follows:

FUNCTION switch to CAP. QUAL.

RANGE switch to CAP. QUAL.

D dial to 0.

Experiment 3-2—Capacitor Quality Tests

VOLTAGE control to 0.

OSCILLATOR switch to SET METER.

Advance the VOLTAGE CONTROL until the PANEL METER reads full scale. Then proceed as follows:

Turn OSCILLATOR switch to OPEN.

Set OSCILLATOR ADJUST until PANEL METER reads full scale. Now the meter is calibrated and the clips may be connected to C9, the capacitor to be tested. Connect the ground lead of the cable to the side of the capacitor nearest ground, in this case pin 8 of V4 (A-19L). Connect the positive lead of the cable to the other side of the capacitor (A-20L). If the PANEL METER continues to read full scale the capacitor is open. If the PANEL METER reads anything less than full scale the capacitor is not open and you may proceed with the "SHORT" test. Turn the OSCILLATOR switch to SHORT and again observe the PANEL METER. If it reads full scale, the capacitor is shorted. If it reads anything less than full scale, the capacitor is not shorted.

This test may be used for quick checks of many capacitors without disconnecting each one for testing. When the quality test indicates an abnormality, one end of the capacitor should be disconnected and the capacitor checked for capacitance in the usual manner.

The capacitor quality test of C9 can be considered as a true open and short test since C9 has a large resistor on each side of it. The test does have limitations however, since many capacitors are shunted by low resistances, such as in a high frequency tank circuit. This would give a false indication since the ZM11/U operates at only 1000 CPS and the coil impedance would be low.

Review

In this topic you have studied the use of the ZM11/U Bridge and also performed experiments using it as the test instrument.

The principle points and uses you should have learned are listed below.

1. The operating principle of the capacitance bridge. When measuring the values of a capacitor, the variable capacitance dials are adjusted for balance at maximum shadow angle of the indicator tube. The value is read from these calibrated dials.
2. How to measure values of resistance with the resistance bridge.
3. How to measure values of capacitance.
4. How to make a capacitor quality test for a short and open in a capacitor without removing it from the circuit.

TOPIC 4: SPECIAL TEST PROBES

Probes

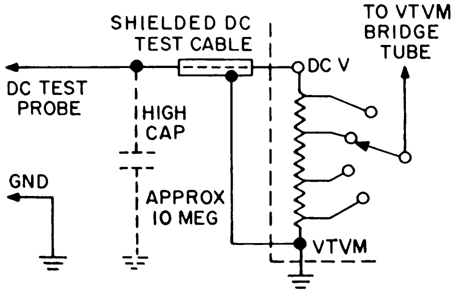
The prime purpose of test equipment used in checking electronic circuits is to show the technician a true picture of what is happening in the circuit under test. When test equipment is applied to a circuit, it becomes, for all practical purposes, an integral part of the circuit. Under certain circumstances this will have the effect of changing the operation of the circuit under test, and readings, on a scope or meter, taken under these conditions would not be a true indication of the circuit operation. For this reason it is sometimes necessary to utilize special probes to minimize the effect the test equipment has on the circuit. A few of these probes will be discussed here. Additional information on probes, usually furnished with the equipment, may be obtained by referring to the operating manual for the equipment.

Resistive Circuit-Isolation Probe (The DC Probe)

The simplest and perhaps most widely used DC circuit-isolation arrangement is that provided by the 1-megohm resistor which is included in the "DC Probe" of practically all service-type VTVMs, for use on the DC voltage ranges. This isolating resistor has two important functions: (1) it greatly reduces the effective over-all input capacitance presented to the circuit under test by the VTVM; (2) it comprises part of a resistance-capacitance input filter circuit which filters out any strong high-frequency AC components that may be present in the DC voltage that is to be measured, thus preventing them from reaching the metering circuit, so that DC voltages can be measured in the presence of high-frequency AC.

Action as a Circuit-Isolation Resistor

The input voltage-divider resistance network, shielded input cable, and test probe of a VTVM have a combined overall capacitance which may total approximately 60 to 120 uuf or more. If an isolation resistor were not used, this capacitance would be applied directly across the circuit whose DC voltage was being checked, as shown below. Such a large value of shunting capacitance will cause severe capacitive loading and disturbance of the normal circuit operation of many of the r-f circuits whose DC

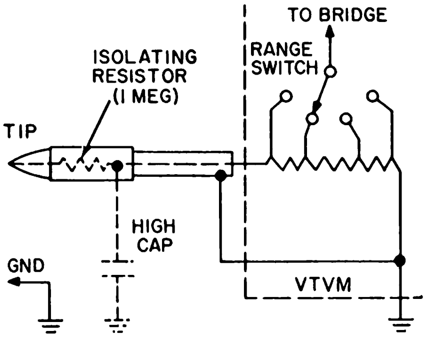


12. —Capacitance Loading Effect.

Probes (Continued)

voltages need to be checked with VTVM, resulting in erroneous and misleading DC voltage readings. An example is provided by an attempt to measure the signal-developed DC bias voltage at the control-grid of a high frequency oscillator. It is not practical to dispense with the shielded cable in an effort to reduce the capacitance, since excessive spurious voltages would often be induced in an unshielded cable by the strong stray fields existing around the equipment under test. The problem is solved by inserting a suitable isolating resistor R, below, having a value of approximately 1 megohm, in series with the input circuit, between the shielded cable and the test point in the receiver.

The effect of introducing the large-value isolation resistance at this particular point in the circuit is to place it in series with the reactance of the overall input capacitance C. When a resistor is connected in series with a capacitor, the series combination has an impedance larger than the reactance of the capacitor alone, for any given frequency. Therefore, the addition of this isolation resistor greatly increases the impedance of the input circuit as seen from the probe tip. This is equivalent to saying that the input capacitance has been reduced in effect, to a value C1, whose reactance is equivalent to this impedance at the particular frequency being considered.



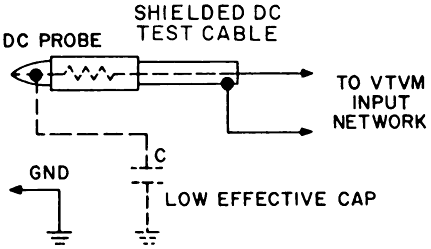
13.—Probe with Isolating Resistor.

Another viewpoint regarding the effect of the isolating resistor is that its resistance value is sufficiently high (usually about 1 megohm) to provide protection against the shunting effect of the low impedance presented by the cable at high frequencies. The isolating resistor is between the high-frequency voltages in the circuit under test, and the low impedance presented by the input end of the cable, which may drop to as low as 75 ohms at high frequencies.

Its practical effect is to provide negligible capacitive circuit-loading and resonance effects for most VTVM DC voltage measurements made in radio-frequency circuits, so that little or no detuning, or other disturbance, of such circuits under test is caused by connection of the DC probe of the VTVM to a load-sensitive point in the circuit. Addition of this 1-meg resistor in series with the usual 10- or 25-meg input network resistance of most VTVM's, above, results in a total DC input resistance of 11 or

Probes (Continued)

26 megohms, respectively, which is great enough to prevent serious resistive loading of most tested DC circuits, including DC grid bias circuits. The most satisfactory arrangement is to mount the resistor within the DC probe head as shown below.



14. —Isolation Probe.

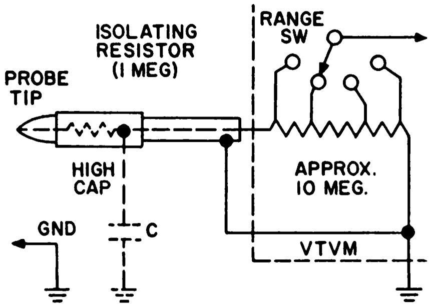
Reduction of the effective input capacitance at the probe tip to a value of only 1 or 2 uuf is common, as shown above. Of course, the probe assembly has a certain amount of stray capacitance from its input to its output circuit, and from its input to ground, which is included in this effective input capacitance. Obviously, these two stray capacitances should be kept as small as possible by proper physical design of the probe.

Action as a High-Frequency Filter

It may be seen that the combination of the series isolating resistor with the over-all shunt input capacitance, also forms a low-pass resistance-capacitance divider for AC potentials. When the frequency is fairly low, the capacitive reactance is fairly high, so that the isolating resistor does not drop very much applied AC voltage. When the frequency is higher, the capacitive reactance becomes fairly low, so that the isolating resistor drops practically all of any applied AC voltage. This provides sufficient high-frequency attenuation to keep any strong high-frequency components (such as RF) that may be present in the DC voltage under test from the metering circuit.

As shown on the adjacent page, the isolating resistor is in series with the resistors that form the voltage-dividing network across the VTVM input. The resistance of the latter is 10 megohms in many commercial VTVM's. Consequently, a portion (about 10 percent in this case) of the applied DC voltage that is to be measured will appear as a voltage drop across the isolating resistor, and the remainder (about 90 percent) will be applied to the VTVM. This reduces the meter deflection produced for a given input test voltage.

Probes (Continued)



15. —Isolation Probe.

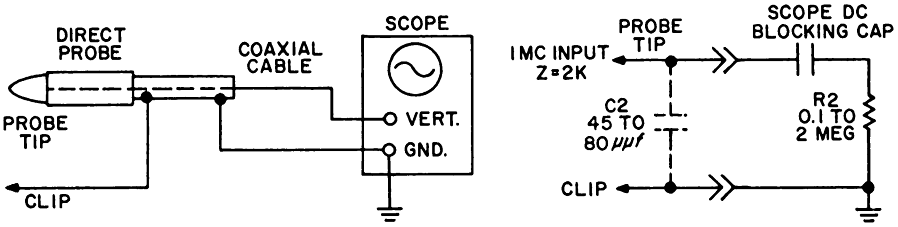
An isolation probe is supplied as standard equipment with most VTVMs, and the meter is calibrated for use with this particular probe. No other probe should be used unless it is known to be of the same values. Any other probe will give false meter readings. The manufacturer's instruction book will give the value of probe and meter input resistance.

Low Capacitance Probe

The internal vertical input circuit of an oscilloscope consists of resistance and capacitance. The amount will vary on different types of scopes. For instance, the typical input series resistances are on the order of 0.1 to 2 megohms and typical shunt capacitances are on the order of 15 to 30 uuf. Added to this capacitance is approximately 30 to 50 uuf (or more) distributed capacitance when using a direct probe and coaxial input cable. Addition of this shunting resistance and capacitance to some circuits under test would have virtually no noticeable effect on their operation and on the voltage and waveform present at the test point. However, in many cases, this amount of added capacitance may be sufficient to detune resonant circuits, or to capacitively load a circuit enough to seriously distort the waveforms under observation, or alter peak-to-peak voltage values.

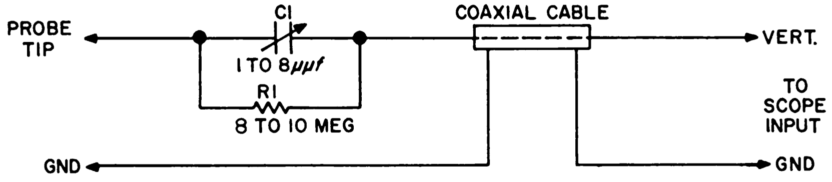
Low Capacitance Probe (Continued)

This would particularly be apparent if the circuit had high impedance or relatively high frequency. For example, the input impedance presented to a circuit with a signal frequency of 1 MC by a typical service scope would be approximately 2,000 ohms, as shown below. To prevent excessive circuit loading, it is necessary to decrease the normal input capacitance (increasing the input impedance). This may be accomplished in a simple and convenient manner by means of a compensated R-C type of circuit-isolation probe commonly known as a "LOW CAPACITANCE" or "HIGH-IMPEDANCE" probe because of its function.



16.—(A) Direct Probe for Typical Scope

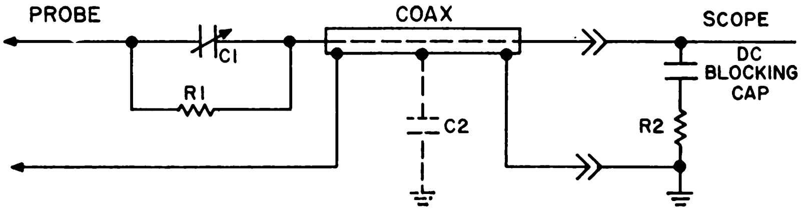
(B) Scope Input Circuit.



17.—Low Capacitance Probe.

The simplest type of conventional frequency-compensated R-C divider "LOW CAPACITANCE PROBE" for use with scopes is shown above. A small semivariable tubular or ceramic trimmer-type capacitor C1, shunted by high resistance R1, is connected in series with the "hot" lead of the shielded test cable to the scope, thereby placing the parallel combination in series with the overall 0.1 to 2 megohm input resistance and the 45 to 80 uuf input capacitance of the scope.

Low Capacitance Probe (Continued)



18. —Low Capacitance Probe Combined with Scope Input Capacitance.

The equivalent circuit is shown above. It is seen that a resistance-capacitance (R-C) divider circuit results. The DC blocking capacitor of the scope is shown, but since it has a large capacitance and therefore a very low reactance, it may be neglected in all high-frequency AC test signal combinations. Since the resultant capacitance of two capacitors in series (C1 and distributed capacitance C2) is less than that of the smaller capacitor, the effective input capacitance at the probe may be made almost any desired fraction of the overall scope input capacitance C2 by suitable choice of the value of the series capacitor C1 in the probe. The use of the resistor R1 also reduces the effective input capacitance of the scope.

Furthermore, since the two capacitors and the two resistors form a voltage divider for applied AC voltages, and the AC voltages which appear across the individual capacitors are in inverse ratio to the capacitances, and directly proportional to the resistances, it follows that the increase in the overall scope input impedance and the reduction of the overall scope input capacitance by a certain ratio is accompanied by a loss of AC signal voltage (in the same ratio) entering the scope. This loss is usually referred to as the attenuation of the probe.

The series capacitor and resistor are usually chosen and adjusted to have a value which makes the attenuation ratio a convenient figure; usually 10 to 1, or 100 to 1. The 10 to 1 probe is the most widely used in service work. Since the AC voltage stepdown ratio is then a decimal fraction, use of the probes with a calibrated scope does not destroy the voltage calibrating factor (or deflection-sensitivity calibration) of the scope. The decimal point is merely moved in the initial calibrating factor of the scope. Thus, if the vertical deflection sensitivity of a particular scope is set for 0.02 volts per inch when it is used with its direct probe and cable, it becomes 0.2 volt per inch when it is used with a 10 to 1 low-capacitance probe.

The utilization of this type of probe with a scope will minimize the effect the scope will have on a circuit under test.

Experiment 4-1—Application of Basic Test Probe

In topic 2 you saw how the VOM loaded down certain circuits. In this experiment you will see how the loading effects of test equipment on a sensitive circuit can be reduced to an acceptable level.

Connect a scope to the plate pin 5 of V2B and adjust for a steady waveform. Now touch the direct probe of the VOM to the grid pin 1 of V2A and observe the effect on the scope. Next clip a 4.7 megohm resistor to the probe tip and touch this to the same point. You should notice very little effect on the scope presentation. The 4.7 megohm resistor is acting as an isolation probe for the meter, reducing the loading effect on the Wien Bridge Oscillator.

Since the VOM is calibrated for use with a direct probe, the 4.7 megohm isolating resistor has reduced the meter reading to a very low value, as most of the voltage is dropped across the isolation resistor. Although it is possible to calculate a multiplication factor by which the voltage could be determined, it is much more practical and accurate to use a VTVM with the standard isolation probe.

Review

In this topic, special test probes have been discussed in some detail. This knowledge will help you in future troubleshooting aboard ship. By using the proper test probes with test equipment, you will not waste time on false indications of casualties due to circuit loading.

The main points of this topic are:

1. The DC Probe, usually furnished with the VTVM, consists of a high value isolation resistor. The meter is calibrated to allow for probe attenuation.

2. The low capacitance probe, for use with oscilloscopes, consists of a frequency compensated RC divider network. The probe attenuation must be accounted for when used with the scope for voltage measurements.

3. Coaxial or shielded test leads are used with these special test probes.

TOPIC 5: CATHODE RAY TUBE

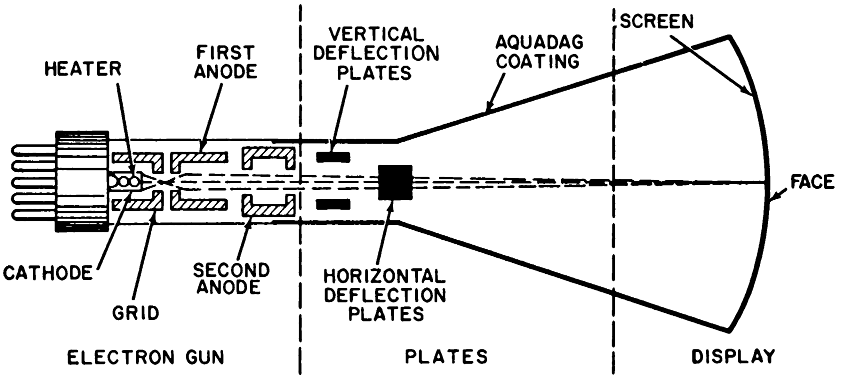
The information given here on the CRT is designed as general information, and does not pertain to a specific piece of equipment. Different CRT's will vary somewhat in construction, but the theory of operation is fundamentally the same in all of them.

The cathode ray tube (CRT) is the heart of the most important piece of electronic test equipment, the oscilloscope. This information sheet has been prepared to acquaint you with the construction and action of the CRT in order that you may understand how it is used in the oscilloscope, and the function of each of the front panel controls on the oscilloscope.

Modern electronic equipments contain hundreds, even thousands of vacuum tubes. To check each tube every time there is an equipment failure is not practical, so there are built in "test points" located throughout the equipment. An oscilloscope properly applied to these "test points" will enable the competent technician to "isolate", or localize a casualty. Once the trouble has been isolated to a particular unit or stage, the technician can use appropriate test equipment to find the malfunctioning component.

The old practice of checking all tubes on a tube tester as a routine periodic preventive maintenance measure, has been disapproved by BuShips. The prescribed POMSEE preventive maintenance procedures use the more practical and economical method of taking voltage checks and waveforms at strategic test points, using an oscilloscope. A new method being implemented is "IMP", Integrated Maintenance Plan, to be used on all weapons systems.

Cathode Ray Tube—General Construction



19.—Cathode Ray Tube.

1. There are two types of CRT's: The electrostatic (voltage) deflection type and the magnetic (current) deflection type. Most oscilloscopes use electrostatic deflection.

2. The "size" of a CRT is determined by the diameter of the face of the tube, and ranges upwards from 1".

Cathode Ray Tube—General Construction (Continued)

3. There are three basic sets of components in the electrostatic deflection type CRT: the electron gun, the deflection plates, and the display screen.

Internal Construction

The internal construction of a CRT is shown on the facing page. It consists of the following components.

1. The Electron Gun is so named because it shoots a stream of electrons at the screen of the CRT. It consists of the filament, cathode, control grid, accelerating anode and focusing anode, in that order, proceeding from the rear to the front of the CRT.

2. The Filament is used to heat the cathode and is powered by AC from a filament transformer.

3. The Cathode emits (gives off) electrons when it is heated. It is the source of the electron stream, and is cylindrical in shape, with a small electron emitting surface to produce a very fine electron stream.

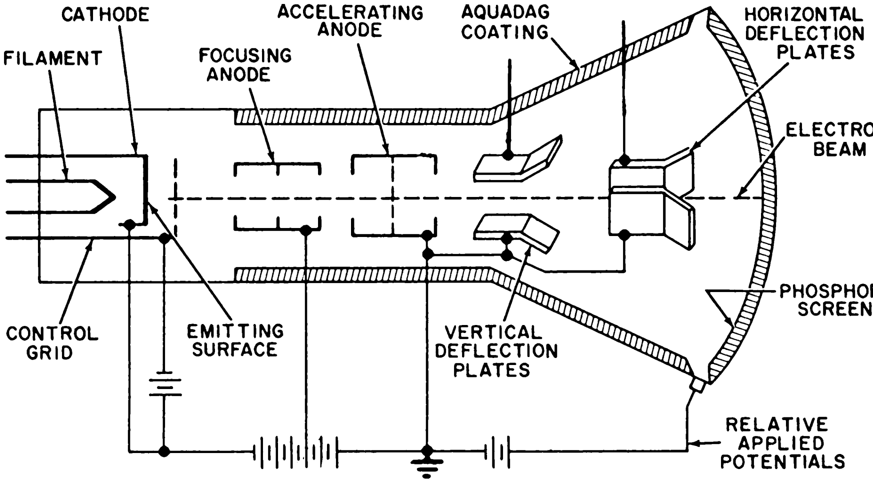
4. The Control Grid is also cylindrical in shape. It regulates the number of electrons in the electron stream which flow past it from the cathode toward the screen of the CRT. Control of the number of electrons flowing past the grid is obtained by varying the applied grid to cathode potential.

5. The Accelerating Anode causes the electrons in the electron stream to travel at a very high rate of speed from the cathode to the screen. Acceleration is obtained by placing a high positive potential on the accelerating anode in respect to the cathode potential.

6. The Focusing Anode controls the size (diameter) of the electron stream to form a "beam" as it flows past the anode towards the screen. Control is obtained by varying the applied potential.

7. The Deflection Plates deflect the electron beam so that the beam can be caused to strike the screen at any point on the face of the CRT. There are two pair of deflection plates: the rear pair is the vertical deflection pair, which allows vertical (up and down) control of the electron stream; the front pair is the horizontal (left and right) control of the electron stream. Deflection is obtained by placing varying voltages on either or both pairs of deflection plates.

Internal Construction (Continued)



20. —CRT Internal Construction.

8. The Display Screen is a phosphor coating on the inside face of the CRT which glows when struck by the electron beam. This phosphor coating has a certain amount of persistency, that is, the glow will remain on the face of the scope for a short time when struck by the beam. The glow will fade rapidly if the beam is cut off or moved to another location on the screen. After the electrons have struck the screen of the CRT, they are collected by the positive aquadag coating painted on the inside walls of the tube, and returned to the power supply.

Action of the Deflection Plates

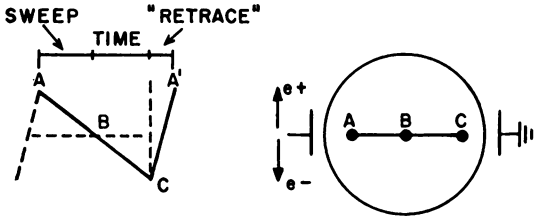
From the study of electrostatic charges created by friction we learned that like charges repel one another, and that unlike charges attract one another. Since electrons have a negative charge it follows that the electron beam in the CRT will have a negative potential, and any negative voltage which is applied to a deflection plate will repel the electrons away from that deflection plate; conversely, any positive voltage applied to a deflection plate will attract the electrons toward this deflection plate.

Horizontal Deflection Plates

If there is no difference of potential between the horizontal deflection plates, the electron beam will flow exactly between them (on the horizontal axis) and strike the center of the screen (assuming no vertical deflection).

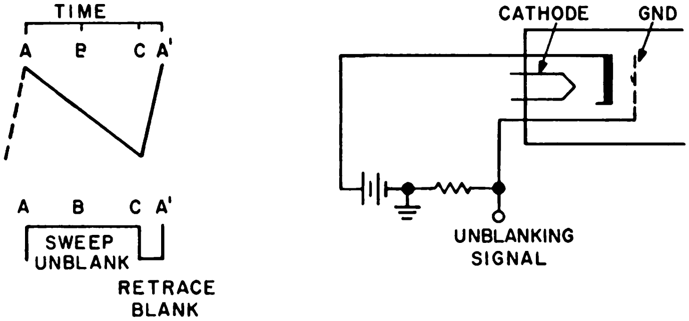
Horizontal Deflection Plates (Continued)

However, if the left plate is made positive in respect to the right plate the electron beam will be attracted towards the left and will strike the screen on the left hand side. The amount of deflection will be proportional to the amplitude of the potential applied to the deflection plates. If a voltage waveform, shown below, is applied to the left hand plate, the electron beam will be first attracted strongly towards the left hand plate (Point "A") and as the voltage becomes less positive, the electron beam will be attracted less and less towards the left hand plate until the voltage reaches zero volts, at which time the electron beam will be positioned exactly between the plates (Point "B"). As the voltage continues to change now in a negative direction, the electron beam will be repelled more and more strongly, until the voltage reaches a maximum negative, at which time the electron beam will have reached its maximum excursion towards the right hand plate (Point "C"). Thus the electron beam will have traveled from the left hand plate to right hand plate, and due to the persistency of the phosphor coating will cause the screen of the CRT to glow in a straight line across the face of the tube. At time "C", the voltage will change from maximum negative to maximum positive to cause the electron beam to rapidly move to the left side of the screen again, (Points C to A') and the entire sequence will be repeated, causing the beam to sweep in a straight line from left to right. This type of voltage waveform is commonly referred to as a sawtooth voltage. As previously shown, during the time that the voltage is changing from points (C to A'), the electron beam will travel from right to left across the screen. If a signal is present on the vertical plates at this time, it could cause an undesirable "retrace" to appear with resultant distortion of the presentation. To prevent this "retrace", some means must be employed to cut off the electron beam during retrace time. There are two general methods of accomplishing this, either by the use of an unblanking pulse or blanking pulse.



21.—Horizontal Sweep Generation.

Horizontal Deflection Plates (Continued)



22.—Unblanking Waveform.

The unblanking pulse is usually a positive square wave applied to the control grid of a normally cut-off CRT. The time duration of this square wave must be just long enough so that the electron beam can sweep from point A to point C, at which time the CRT would again be cut off during retrace time point C to A . This allows the beam to strike the screen only when sweeping from left to right across the screen.

The blanking pulse is usually a negative square wave of short duration applied to a normally conducting CRT. It is applied only during retrace time (point C to A') to hold the CRT in cut off during this time.

Blanking or unblanking voltages may also be applied to other elements of a CRT depending on the CRT design.

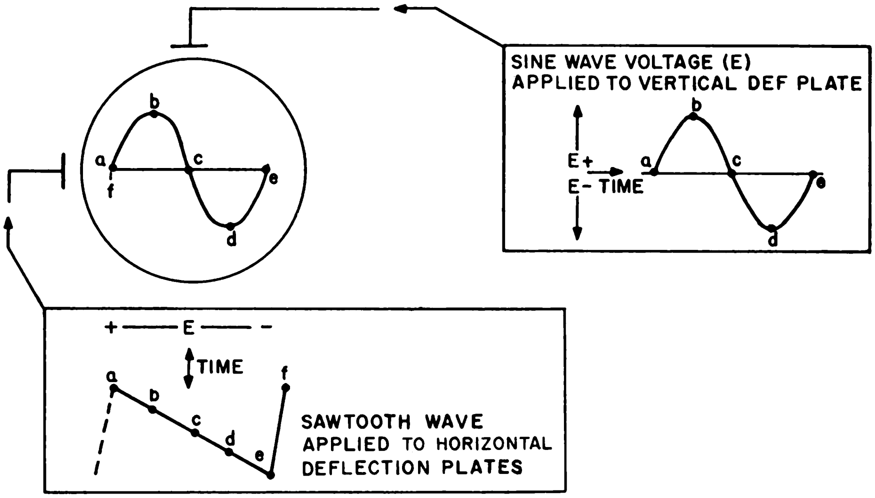
Vertical Deflection Plates

The action of the vertical deflection plates is identical to the action of the horizontal deflection plates in that they will cause the electron beam to be deflected an amount proportional to the amplitude of the potential applied to them and in a direction depending on the polarity of the potential; their effect on the electron beam however, will be on the vertical axis.

Combined Horizontal and Vertical Deflection

If a sawtooth voltage is applied to the horizontal deflection plates at the same time that an AC voltage is applied to the vertical deflection plates, there will be a deflection of the electron beam which is a result of the combined effect of both voltages. As shown on the facing page, at the first instant the sawtooth is maximum positive and the electron beam is attracted toward the left horizontal plate; at the same time, the AC applied to the vertical plates is at zero volts, so the electron beam will pass exactly between the vertical deflection plates (point A), and the result will be that the electron beam strikes the screen at the extreme left hand side of the face of the tube; the sawtooth now becomes less positive, and the electron beam is attracted less strongly toward the left plate; the AC applied to the upper vertical plate is increasing in a positive direction, causing the electron beam to move upward. The AC will

Combined Horizontal and Vertical Deflection (Continued)

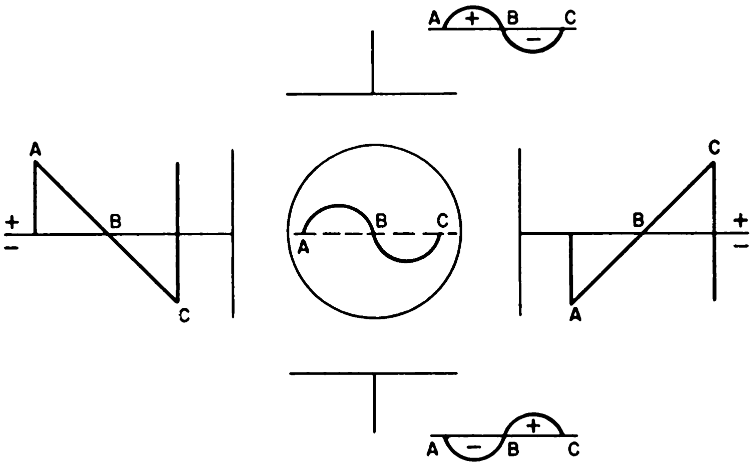


23. —Combined Horizontal and Vertical Inputs.

become more positive causing the electron beam to move upward and the electron beam will follow the combined effects of both, striking the screen in a gradual curve, upward and to the right, until one-fourth (1/4) way through the sequence, at which time the AC will be maximum positive, and the electron beam will be at its maximum upward excursion. The AC then begins to decrease from maximum positive toward zero, causing the electron beam to be attracted less toward the upper plate, and the sawtooth wave continues to be less positive, attracting the electron beam less and less to the left, so that the electron beam strikes the screen in a gradual curve, downward and to the right, until one-half (1/2) way through the sequence, at which time both the sawtooth voltage and the AC voltage is at zero volts, and the electron beam passes exactly between both the horizontal and vertical deflection plates and strikes the exact center of the CRT (point c, above). The sawtooth voltage continues to change, now it is going negative, repelling the electron beam from the left horizontal plate; the AC also is changing in a negative direction, causing the electron beam to be repelled by the upper plate. The combined effect will be that the electron beam strikes the screen in a gradual curve, downward and to the right, until three-quarters (3/4) through the sequence, at which time the AC will be maximum negative and the electron beam is at its maximum downward excursion (point d). The AC then begins to decrease from maximum negative toward zero volts, causing the electron beam to be repelled less by the upper plate, and the sawtooth wave continues to become more negative, repelling the electron beam more and more to the right, so that the electron beam strikes the screen in a gradual curve, upward and to the right, until the completion of one full sequence, at which time the sawtooth is maximum negative and the AC is again zero volts (point e).

Combined Horizontal and Vertical Deflection (Continued)

In normal practice, signal and sweep voltages are applied in balanced push-pull to the vertical and horizontal deflection plates, as shown below.



24. —Push-pull Signals on CRT Deflection Plates.

Usefulness of Action of the CRT

Due to the peristency of the phosphor coating, the screen of the CRT will glow for a brief time after it has been struck by the electron beam, the foregoing explanation shows that the CRT has usefulness in electronics. If the CRT is used where a sawtooth voltage can be applied to the horizontal deflection plates and the vertical deflection plates are connected to an electronic test point, a "picture" of the voltage applied to the vertical deflection plates will appear on the face of the tube. Such an arrangement is provided in the CATHODE RAY OSCILLOSCOPE.

CATHODE RAY TUBE

Review

In this topic you have learned the uses, internal construction and operation of the CRT.

The main points of this topic are:

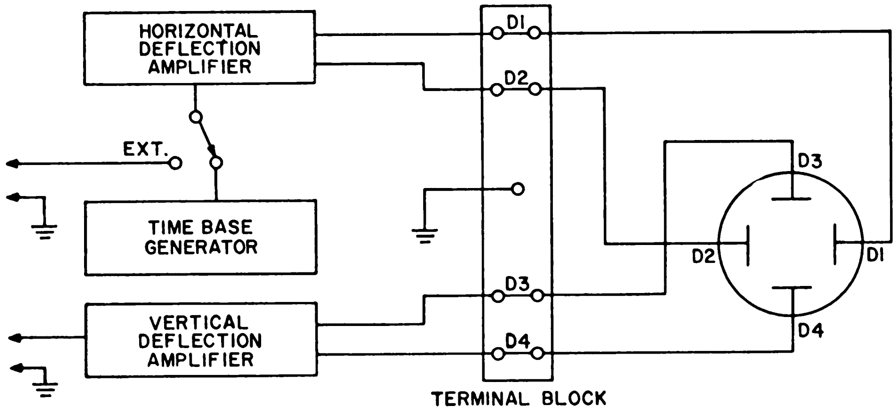
1. The electron gun—parts, construction and functional description.
2. The accelerating and focusing anodes—construction and function.
3. Deflection methods, electrostatic and electromagnetic.
4. Action of the deflection plates on the electron beam.
5. Phosphor coated screen and aquadag coating.

TOPIC 6: GENERAL PURPOSE OSCILLOSCOPE OS-8E/U

The Oscilloscope

The oscilloscope is a test instrument consisting of a cathode ray tube and associated circuits for use in viewing wave shapes of voltages. You have used the oscilloscope constantly since the beginning of your course in Basic Electronics.

You have learned the theory of operation of the cathode ray tube, now, you are particularly interested in the other basic sections of the oscilloscope. These associated circuits include a time-base generator, the horizontal deflection amplifier, and a vertical deflection amplifier as shown below. Another section common to all of these is the power supply.


HORIZONTAL DEFLECTION AMPLIFIER
EXT.
TIME BASE GENERATOR
VERTICAL DEFLECTION AMPLIFIER
D1
D2
D3
D4
D3
D2
D1
D4
TERMINAL BLOCK

25.—Oscilloscope, Block Diagram.

The horizontal deflection amplifier input can either be from the time base generator or an external horizontal signal.

The vertical signal input is normally applied to the vertical amplifier. The vertical and horizontal inputs can be applied directly to the respective plates of the CRT by use of the deflection terminal block connections.

The Oscilloscope (Continued)

Previous discussion of the oscilloscope only mentions viewing waveforms. The value of the oscilloscope as a precision measuring instrument cannot be underrated. You will learn more on the uses, the panel controls, and theory and operation of a general purpose type oscilloscope.

Oscilloscope Uses

In addition to its use in observing wave shapes, the oscilloscope is used for measuring voltages, frequency, phase relations, and time (or period) of a waveform.

A voltage is measured by comparing the deflection it produces with the deflection produced by a known voltage. Do not change the vertical gain control while comparing the deflections. Since deflection is proportional to voltage, this is a very good method for measuring peak voltage of odd waveshapes. First apply the known voltage and then adjust the VERTICAL GAIN control for the desired picture. Measure the peak amplitude accurately. Do this with a ruler and dividers or by counting squares on the graticule in front of the screen. Apply the unknown voltage and take a similar measurement. By comparing deflections, you may obtain the ratio of the peak voltages and determine the unknown voltage. The RMS value of a sine wave can be calculated by multiplying the measured (peak-to-peak) value times .354.

Oscilloscope Uses (Continued)

Frequency measurement can be made by two methods.

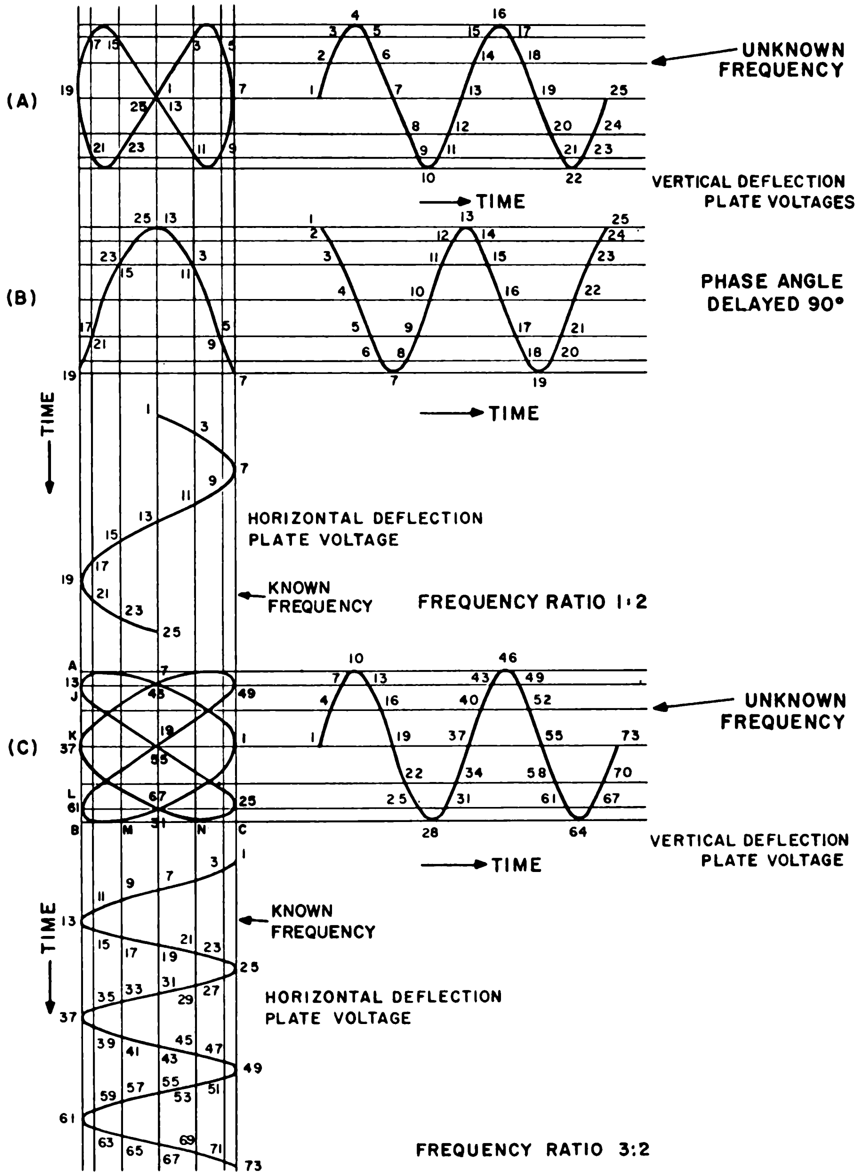
When AC signals are applied to the vertical and horizontal inputs of an oscilloscope certain definite patterns will result which will be dependent upon the frequency ratio of the signals applied. These patterns are called Lissajous patterns.

The first method is to compare the unknown frequency with a known frequency by applying them one at a time to the vertical deflection plates and then comparing the number of cycles which appear. The frequency controls must not be changed during the comparison. Unless the two frequencies have an integral ratio, this method is just a good approximation.

The second method for determining the frequency of a sine wave is to apply the unknown frequency to the vertical deflection plates of the oscilloscope CRT and the known frequency sine wave to the horizontal deflection plates. The frequency ratios resulting from the application of the known and the unknown frequencies are shown on the facing page. Note, that the phase angle difference alters the picture of the wave shape in B. The ratio is established by counting the peaks of the pattern at the top or bottom and on one side. The frequency of the unknown in (A) and (B) is twice the known frequency. The frequency of the unknown signal in (C) is two thirds the known frequency, therefore the ratio is 3:2.

A simple Lissajous pattern displayed on a CRT is the circle. The principle on which the circle generator functions is much used in Fire Control radars. A circle can be produced on a CRT by two sine wave voltages differing 90^{o} in phase having the same frequency and amplitude. Thus, phase comparison can be made with the oscilloscope of two AC signals having same frequency and amplitude.

Oscilloscope Uses (Continued)

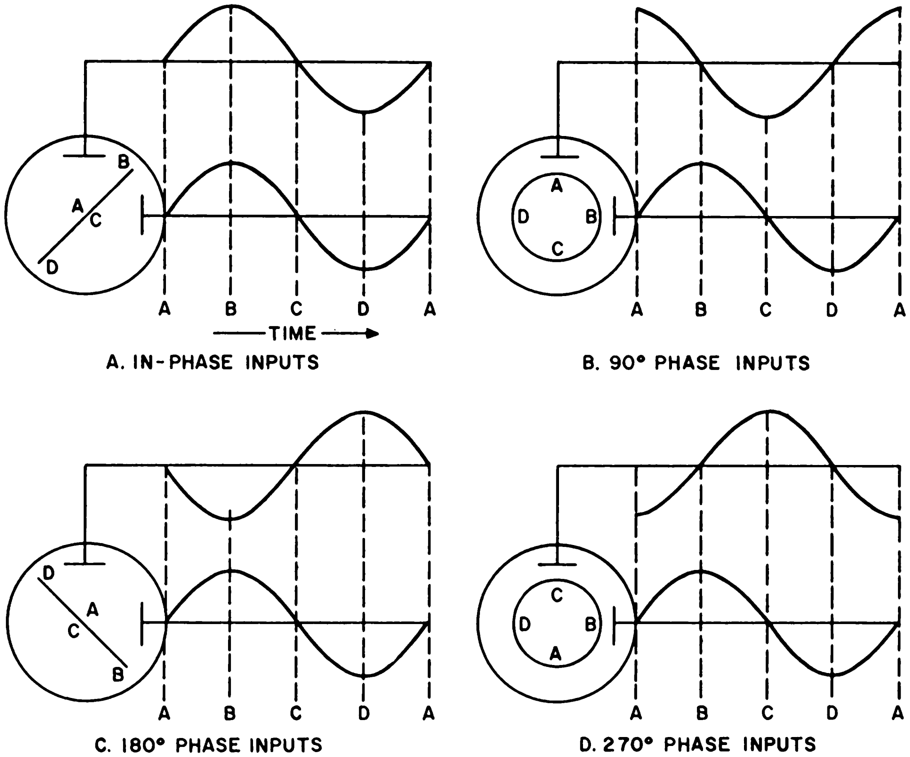


26.—Lissajous Patterns.

Oscilloscope Uses (Continued)

Shown below (A), two in phase sine waves of equal amplitude are applied to the vertical and horizontal deflection plates. At time "A", both signals are at zero amplitude, so the beam will not be deflected and will strike the center of the CRT screen. As both voltages increase in a positive direction (time "A" to "B"), the beam will sweep up and to the right at a 45 degree angle. From time "B" to "C", both signals decrease to zero, and the beam will retrace to the center of the screen. On the negative half cycle, the beam will be deflected down and to the left to time "D", then retrace to the center as the cycle ends.

Electron beam deflection can be followed in the diagrams below for various out-of-phase inputs.



A. IN-PHASE INPUTS

B. 90° PHASE INPUTS

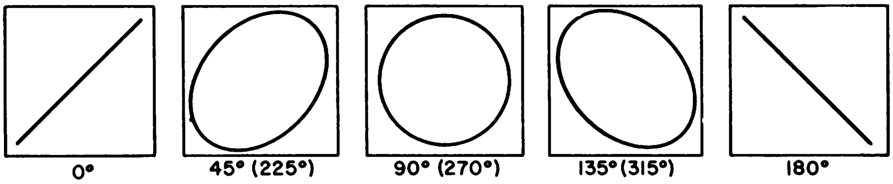
C. 180° PHASE INPUTS

D. 270° PHASE INPUTS

27.—Phase Comparison.

Oscilloscope Uses (Continued)

By analyzing (B) on the facing page in the same manner, it can be seen that two voltages applied 90° out of phase, but of equal frequency and amplitude, will result in a circle. (C) shows the two voltages 180° out of phase resulting in a straight line slanting to the left. Shown below are a group of Lissajous figures illustrating phase differences from 0° to 180°.



28. —Phase Difference Patterns.

Theory of Operation

The OS-8E/U is a typical oscilloscope of a type that is used through-out the navy for checking amplifiers, power supplies, and in general audio and low radio frequency circuits.

The oscilloscope shown on page 49 is an earlier model of this scope. Since you have used this type scope in your practical training, you are then familiar with the controls and their effect on the display.

Theory of Operation (Continued)

So that you may better understand and operate this and other scopes, the functional signal flow of its internal circuits will be covered. Shown on the facing page is a block diagram. Notice the circuits are functionally divided into sections; vertical, horizontal, and synchronizing sections.

In the vertical section, the normal input in some type of AC signal. This signal is applied to the VERT. ATTEN. switch so the larger signals may be reduced in size when necessary.

On the VERT. ATTEN. switch there are three AC positions and one DC position. The DC position is effectively a short past the switch so that when a DC voltage is applied at the vertical DC input jack it is bypassed directly to the first DC amplifier stage.

The AC signal, after it has been attenuated, is applied to the vertical cathode follower. The variable VERT. GAIN control is in the cathode circuit of this stage. From this stage the signal is sent to amplifiers where the signal is amplified and inverted to provide two signals, 180 degrees out of phase, to be applied to the vertical plates of the CRT. A portion of the signal is also taken from the cathode of the vertical output tubes to be applied as internal sync to the SYNC SELECTOR switch.

The horizontal section has a five position switch to select the input to the horizontal amplifiers. The normal position is the SWEEP position in which a sawtooth signal is applied from the sweep oscillator shown on facing page.

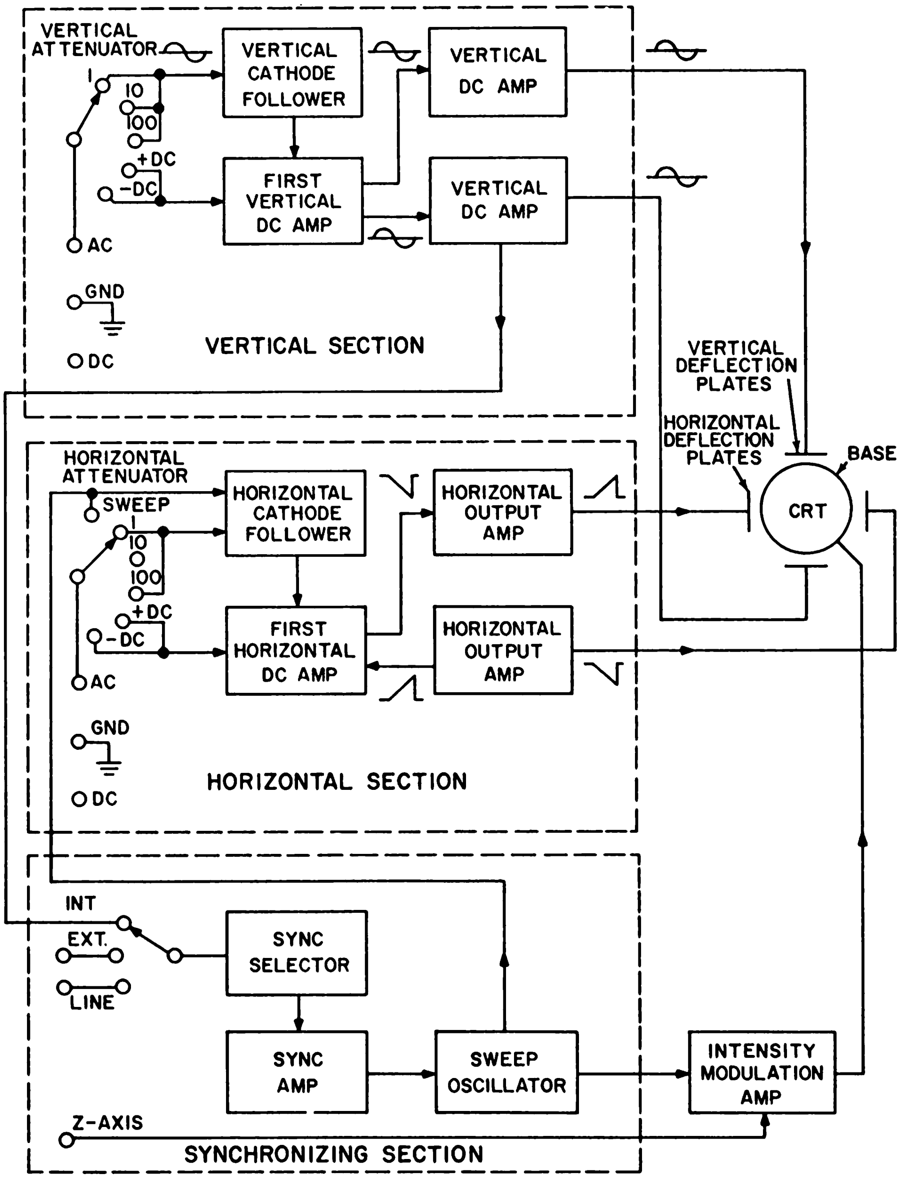
If an AC signal is to be applied to the horizontal section it may be applied through the HOR. ATTEN. switch in three different AC positions.

In the DC position the signal is applied directly to the 1st DC amplifier. Assuming that the HOR. ATTEN. switch is in the SWEEP position, a sawtooth is applied to the horizontal cathode follower. The HOR. GAIN control is in the cathode circuit of this tube. The signal is then sent to the 1st DC amplifier which amplifies and inverts the sawtooth and sends two sawtooths, 180 degrees out of phase, to the output amplifier.

The HOR. POS. control is also in the 1st DC amplifier circuit. The signal is further amplified in the output DC amplifiers and sent to the two CRT horizontal plates 180 degrees out of phase.

The Synchronizing Section serves to synchronize the presentation on the scope to some trigger. The trigger to be used is selected by the SYNC SELECTOR switch which has three positions; INT, EXT, and LINE. When set on the INT. position, a portion of the signal is fed back from the vertical amplifier to aid in synchronizing the sweep. When set on the EXT. position a trigger is applied from an external source to the external jack to synchronize the sweep. When set on the LINE position a 3.15VAC signal is fed in from the line frequency to synchronize the sweep.

Theory of Operation (Continued)



29.—Oscilloscope, Block Diagram.

After the desired trigger has been selected with the SYNC SELECTOR switch, it is applied to a sync amplifier and then to the sweep oscillator, which creates the sawtooth sweep voltage.

Theory of Operation (Continued)

This voltage is sent to the horizontal section to provide sweep when the HOR. ATTEN. is in the SWEEP position.

A portion of the sweep oscillator output is also sent to the intensity modulation amplifier to provide blanking voltage during the retrace time on the CRT.

Another input is also possible to the intensity modulation amplifier. This is the Z AXIS input applied to the Z AXIS input jack. A negative trigger applied at this jack will cause bright spots to appear on the sweep at the frequency of the Z AXIS input signal. If the input frequency is known and stable, the oscilloscope sweep can then be calibrated in time from one bright spot to the next. A positive trigger applied at the Z AXIS jack will cause blanking or dark spots on the sweep.

Panel Controls on an Oscilloscope

The controls explained here and shown on facing page are the controls found on most oscilloscopes. Locations and names of the controls will vary on different scopes but functions of the controls will vary little.

A. INTENSITY control

The "INTENSITY" control usually serves two purposes. It is the power on-off switch and the brilliance control. It should be adjusted for convenient viewing. When the scope is not in use, the intensity should be turned down so that the beam cannot be seen, otherwise a spot will be burned in the phosphor coating on the internal face of the CRT. On some scopes the "POWER ON-OFF" switch is a separate control.

B. FOCUS control

The "FOCUS" control adjusts the clarity of the picture. It should be adjusted for the most clearly defined scope pattern.

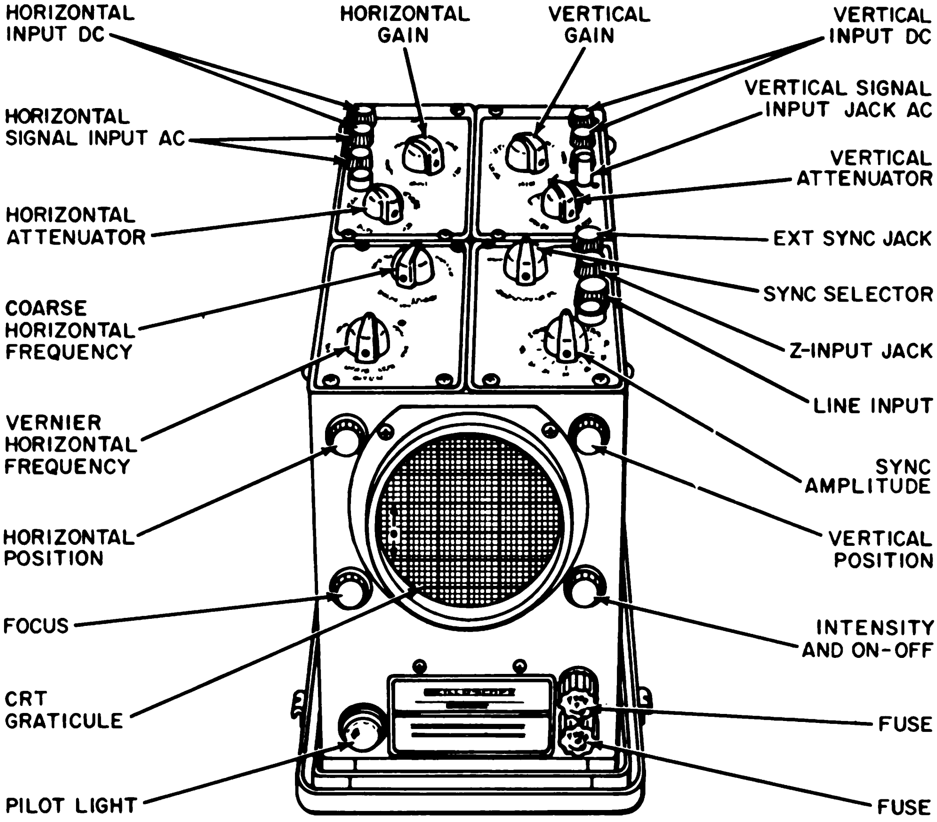
C. "VERT. POS." control

The "VERT. POS." control is employed to vary the vertical position of the CRT pattern. Counter-clockwise rotation of the knob moves the pattern down, clockwise rotation of the knob moves it up.

D. "HORIZ. POS." control

The "HORIZ. POS." control is employed to vary the horizontal position of the pattern. Counterclockwise rotation moves the origin of the sweep and thus the entire pattern to the left. Clockwise rotation shifts the pattern to the right.

Panel Controls on an Oscilloscope (Continued)



30.—Controls and Input Connections of the OS-8C/U Oscilloscope.

E. "VERT. GAIN" control.

The "VERT. GAIN" control is used to control the vertical size of the pattern.

F. "HORIZ. GAIN" control

The "HORIZ. GAIN" control is utilized to control the horizontal amplitude or width of the pattern.

G. 'Y' AXIS INPUT SELECTOR Switch

The " 'Y' AXIS INPUT SELECTOR" switch is usually marked "DIRECT" or "AMPLIFIER". The switch will be normally left in the "AMPLIFIER" position. In the "DIRECT" position; the waveform that you wish to view is applied directly to the vertical plates of the cathode ray tube. At this time the "VERT. GAIN" control is

Panel Controls on an Oscilloscope (Continued)

inoperative. In the "AMPLIFIER" position, the signal is first fed into an amplifier to enlarge the waveform before it is applied to the vertical deflection plates. This switch is not found on all scopes.

H. SYNC SELECTOR Control

The "SYNC SELECTOR" control usually has three positions: "INT", "EXT", and "LINE". On the "INT" position a portion of the signal applied to the vertical plates is fed to the horizontal sweep circuit synchronizing the sweep circuit to the frequency of the signal applied to the vertical plates. In the "EXT." position, an external signal source may be employed to synchronize the sweep frequency. The external signal would be applied at the "SYNC IN" jack or terminal. When using external sync, the horizontal sweep starts at the same point in relation to time on each cycle making it possible to observe phase relationship. In the "LINE" position, a small portion of the line voltage is fed to the sweep circuits and used to synchronize the horizontal sweep to the line frequency.

The operating controls for the general purpose oscilloscope are shown on the facing page.

I. SYNC AMP (or LOCKING) Control

The "SYNC AMP" or "LOCKING" control is used to adjust the amount of signal fed from the vertical plates to the sweep circuits for synchronization. This control is used in conjunction with the "FINE FREQ" control to stabilize or stop the scope presentation.

J. TIME BASE COARSE FREQUENCY Control (COARSE HORIZ. FREQ.)

The "TIME BASE COARSE FREQUENCY control" is employed to control the frequency at which the sweep moves across the face of the CRT. It usually has 5 to 7 positions, each covering a range of frequencies. A coarse selection of the sweep frequency you desire may be set in here. The "COARSE FREQUENCY control" is used in conjunction with the "FINE FREQUENCY control".

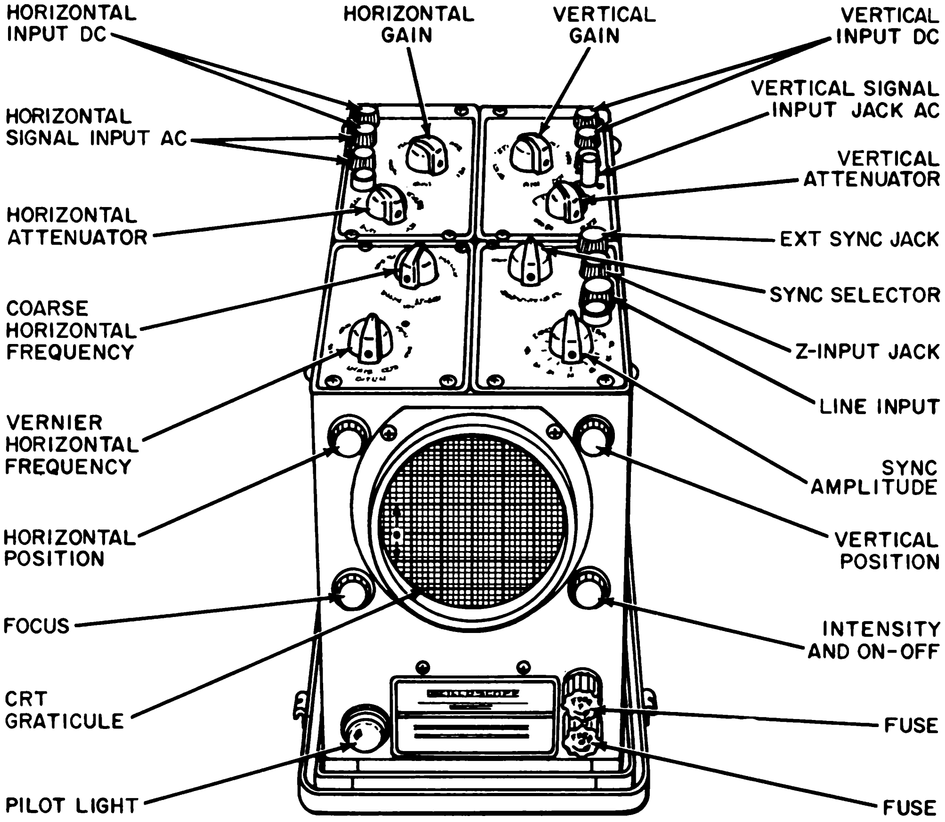
K. FINE FREQUENCY Control (VERNIER HORIZ. FREQ.)

The "FINE FREQUENCY control" is used to select a definite frequency within the range you have selected with the COARSE FREQUENCY control. This is done to stabilize or stop the picture on the scope.

L. 'Y' INPUT (VERT INPUT)

The 'Y' INPUT terminals are normally used to inject the signal to be viewed on the screen. The " 'Y' INPUT" switch determines whether or not the amplifier is used.

Panel Controls on an Oscilloscope (Continued)



31.—Controls and Input Connections of the OS-8C/U Oscilloscope.

M. 'X' INPUT (HORIZ INPUT)

The " 'X' INPUT" terminals may be used to inject an external signal on the horizontal plates either directly or through the horizontal amplifier.

N. 'Z' INPUT

The " 'Z' INPUT" terminal is less frequently used. It is employed when it is desired to have the intensity of the horizontal sweep vary at a definite rate such as for timing marks, range marks, etc.

O. TEST SIGNAL Jack

The "TEST SIGNAL" jack found on some scopes provides an accurate low voltage AC for external use or to calibrate the scope for taking voltage measurements.

Panel Controls on an Oscilloscope (Continued)

P. EXTERNAL SYNC jack

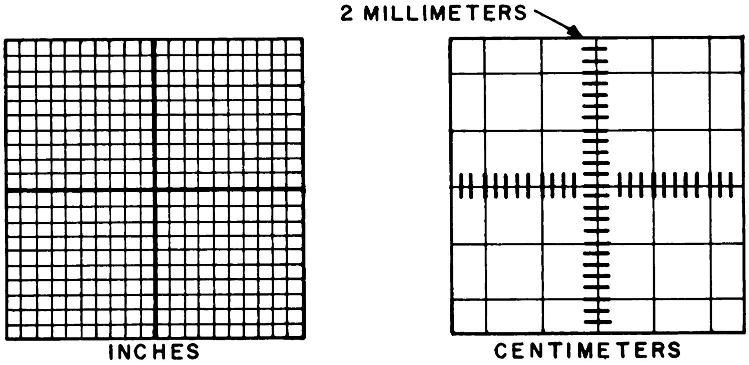
The "EXTERNAL SYNC" jack is used to inject a signal into the synchronizing circuits to start each sweep at the same point in respect to time. To accomplish this, the SYNC SELECTOR switch must be in the EXTERNAL position. The signal to be injected is usually obtained from the same circuit from which you plan to take waveforms.

> Note: The switches and terminals mentioned herein will be found on most scopes. Additional switches may be found on more advanced equipments. Information on these switches may be obtained by referring to the manufacturer's manual for the equipment. Many scopes also have special probes. The uses and descriptions of these probes will also be found in the manufacturer's manual, and will be discussed later as the need arises.

Oscilloscope Graticule

The use of an oscilloscope graticule makes analysis of observed waveforms less difficult for you, the technician trainee.

A graticule is composed of a transparent plate having ruled lines both horizontally and vertically. The projections of the ruled lines have divisions either in inches or centimeters as shown below. Inch divisions are usually sub divided into one/tenth inch lines and the centimeter divisions are usually sub divided into two/tenth centimeter marks (2 millimeter).

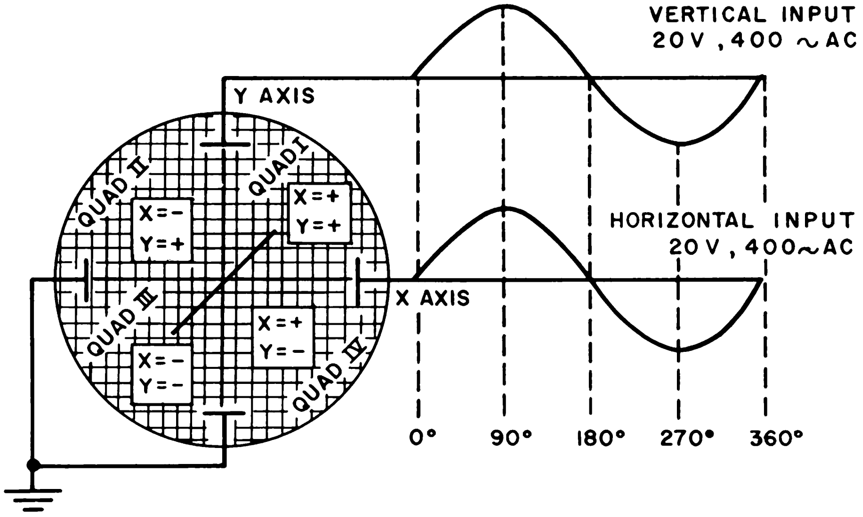


32.—Types of Oscilloscope Graticules.

The graticule is placed in front of the face of the CRT. It is held in place by a bracket and can be replaced by the technician with a graticule of another tint or projection.

Oscilloscope Graticule (Continued)

The discussion on phase comparison covered two AC sine wave signals applied to the vertical and horizontal plates respectively. The beam is deflected by these two equal amplitude, in phase, and same frequency signals as shown below.



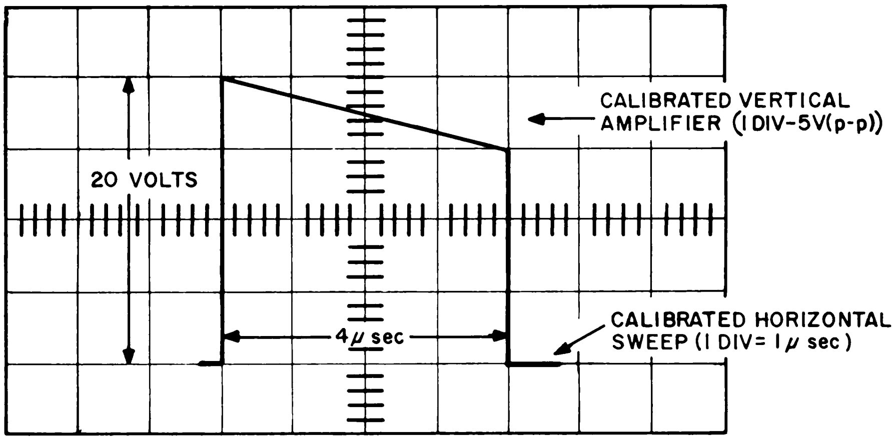
33.—Quadrant System.

The graticule can be visualized to represent the four quadrants of the system of rectangular co-ordinates. The vertical deflection plates cause deflection along the Y axis and the horizontal deflection plates cause deflection along the X axis. If the algebraic sign of the AC inputs are as shown for x and y in a specific quadrant, then the beam will be deflected to that quadrant.

Oscilloscopes that use a calibrated horizontal sweep have a TIME/DIV. control. When one micro-second time is selected each centimeter on the graticule is equal to one micro-second time on the horizontal sweep.

Oscilloscope Graticule (Continued)

Oscilloscopes that use a calibrated vertical amplifier have a VOLTS/DIV. control. When the VOLTS/DIV. is set to the 5 position, each vertical centimeter on the graticule is equal to five volts. The amplitude and time base of waveforms can be precisely measured as shown below.


20 VOLTS
CALIBRATED VERTICAL AMPLIFIER (I DIV-5V(p-p))
4μ sec
CALIBRATED HORIZONTAL SWEEP (I DIV= Iμ sec)

34. —Amplitude and Time Measurement.

The graticule provides a standard reference for oscilloscopes when they are used for making phase comparison, amplitude and time measurements and observing Lissajous patterns of waveforms.

Experiment 6-1—Phase Comparison of the Wien Bridge Oscillator

In order to study the phases of the various voltages in the Wien Bridge Oscillator in relation to each other, the scope must first be synchronized to a reference frequency. This reference frequency, or sync voltage, must be taken from some point that has a common time relationship to the circuitry under test. The sync voltage, when properly applied to the horizontal sweep circuit of the scope, will serve to initiate each sweep at the same point in each cycle of operation. This makes it possible to compare all other signals in the circuit to the common reference of the sync voltage. Refer to NAVPERS 92213A Vol. 1, page 23, 24 and 25 for set-up.

In this experiment, the sync voltage will be taken from the cathode of V2B, since this signal is common to all other signals in the oscillator. For instance, when the cathode signal is maximum positive, the plate signal should be maximum negative and this will occur on each succeeding cycle. Therefore they can be said to be common to each other since they have a definite time relationship. If a lead is connected from the cathode of V2B to the EX SYNC OR SYNC IN jack of the scope and the SYNC SELECTOR switch is turned to EX, the signal at the cathode becomes

Experiment 6-1—Phase Comparison of the Wien Bridge Oscillator (Continued)

the sync voltage. The phase of all other signals in the circuit may now be compared to the phase of the cathode signal or to each other. This is an accepted method of phase comparison that can be used to good advantage in troubleshooting electronic equipment.

Experiment 6-2—Phase Comparison of Wien Bridge Oscillator Using Direct Inputs

Another method of making phase comparison of voltages is to connect one signal to the vertical signal input and the other signal to the horizontal signal input and observe the resulting Lissajous pattern.

The oscilloscope set-up will be normal except the vertical and horizontal attenuators will be set to their AC position.

NAVPERS 92213A Vol. 1 pages 23, 24, and 25 may be used as a reference for location of the test terminals.

Perform the following steps:

1. Connect lead from "VERTICAL SIGNAL INPUT AC" jack to plate, pin 5 of V2B (A-8R). Adjust the VERT ATTEN and GAIN for an amplitude of two inches. Disconnect lead from pin 5.
2. Connect lead from "HORIZONTAL SIGNAL INPUT AC" jack to cathode, pin 6 of V2B (A-6L). Adjust the HOR. ATTEN. and GAIN for an amplitude of two inches.
3. Reconnect lead from "VERTICAL SIGNAL INPUT AC" jack to plate, pin 5 of V2B (A-8R).
4. Observe Lissajous pattern, should be straight line slanted from the upper left quadrant (315^o) into the lower right quadrant (135^o), indicating 180^o out of phase.
5. Connect the lead from the "VERTICAL SIGNAL INPUT AC" jack to grid, pin 4 of V2B (A-5L).
   Lissajous pattern should be a straight line from the upper right quadrant (045^o) into the lower left quadrant (225^o), indicating two signals in phase.
6. Connect lead from "VERTICAL SIGNAL INPUT AC" jack to cathode, pin 6 of V2B (A-6L).
   Lissajous pattern should indicate in phase signals.
7. Connect lead from "HORIZONTAL SIGNAL INPUT AC" jack to plate, pin 5 of V2B (A-8R).
   Lissajous pattern should indicate 180^o out of phase signals.

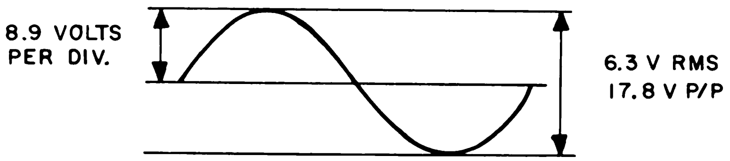
Experiment 6-2—Phase Comparison of Wien Bridge Oscillator Using Direct Inputs (Continued)

8. Connect lead from "VERTICAL SIGNAL INPUT AC" jack to grid, pin 4 of V2B (A-5L).
   Lissajous pattern should indicate two signals 180° out of phase.

Experiment 6-3—Measuring Voltages of a Limiting Circuit with an Oscilloscope

It is sometimes desirable, when checking electronic circuits, to determine the amplitude of a signal on a scope at the same time that you are observing the type of waveform present. The voltage amplitude can be measured with the scope if the proper procedure is followed. Refer to NAVPERS 92213A Vol. 1 page 45 for the following experiment.

In this experiment you will determine the amplitude of the square wave on the plate, pin 5(A-11L) of V3B. In order to accomplish this, the scope must first be calibrated to some known voltage. The voltage you will use for calibration is the 6.3 volt filament supply available between terminals 6 and 8 of the power supply transformer T1. (Note: Some scopes have a calibration voltage available either internally or at an external jack). Connect terminal 6 of T1 to the VERT IN jack of the scope. Connect terminal 8 to T1 to the scope ground connection. Adjust the VERT GAIN control on the scope until the signal is 2 squares high on the CRT grid screen. Do not adjust the VERT GAIN for the rest of this experiment. Next connect the scope vertical input lead to plate pin 5 (A-11L) of V3B. Adjust R-11 until a square wave appears on the scope. Count the number of squares on the grid screen that the square wave covers vertically and multiply by 8.9. Since 6.3 is the RMS value of the sine wave used for calibration, you must multiply by 1.414 to determine PEAK value or the voltage represented by EACH division (below). This gives a multiplication factor of 8.9 volts per division. EXAMPLE: Assume that the square wave was 16 squares high. Then the voltage amplitude will be 16 times 8.9 volts or 142.4 volts peak-to-peak.



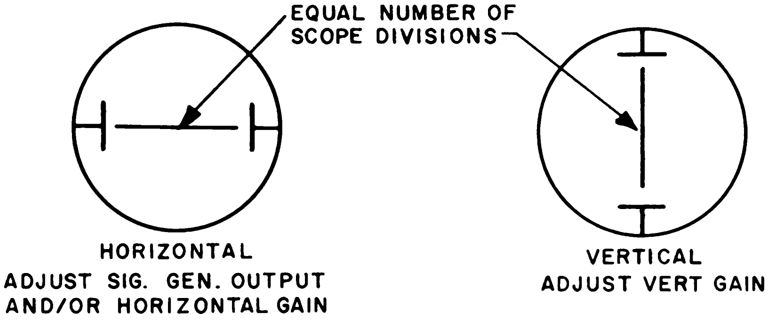
35.—Scope Calibration.

Experiment 6-4—Frequency Measurement Using an Oscilloscope

In this experiment you are going to determine the operating frequency of your Wien Bridge Oscillator. One accepted method of accomplishing this, is by comparing the output frequency of the oscillator with a known frequency. In this case, the known frequency will be the output of an audio signal generator. The scope will be utilized to make the comparison. The output of the Wien Bridge Oscillator will be applied to the vertical deflection plates and the output of the audio signal generator will be applied to the horizontal deflection plates.

In actual practice it is difficult to maintain an exact frequency, so that the presentation will vary slowly, from a straight line, to an ellipse, to a circle, and back again. This is what you will be looking for in this experiment. When this occurs, you can assume that the frequency of the Wien Bridge Oscillator is the same as the frequency of the audio signal generator.

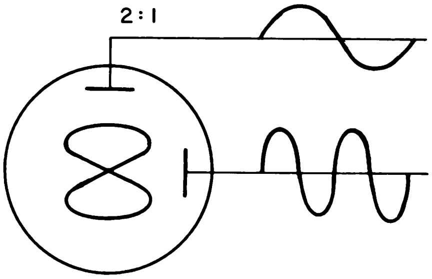
Before Lissajous patterns can be properly displayed, the two input voltages at the deflection plates must be equal in amplitude. To accomplish this, apply one voltage at a time and adjust the input and/or gain for equal length of horizontal and vertical lines.


EQUAL NUMBER OF SCOPE DIVISIONS
HORIZONTAL
ADJUST SIG. GEN. OUTPUT AND/OR HORIZONTAL GAIN
VERTICAL
ADJUST VERT GAIN

36.—Preliminary Adjustment.

Experiment 6-4—Frequency Measurement Using an Oscilloscope (Continued)

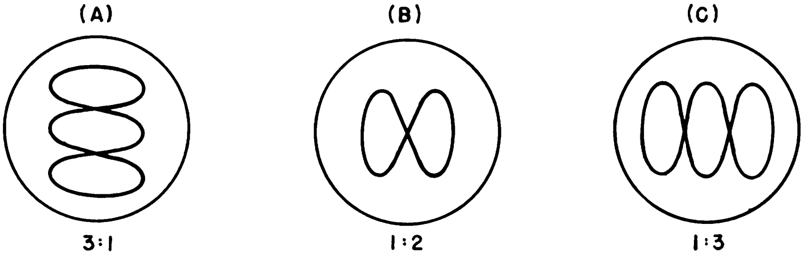
After you have determined the operating frequency of your Wien Bridge Oscillator and recorded it (page 27, para 2, NAVPERS 92213A Vol 1), increase the frequency of the signal generator to exactly twice this recorded reading. Your scope should then have a presentation similar to that shown below. This indicates that the horizontal signal is exactly twice the frequency of the vertical signal.



37.—Frequency Comparison.

Now increase the signal generator frequency to exactly three times your recorded reading. You should have a presentation similar to (A) below.

You are now going to see what happens when the signal on the vertical deflection plates is a higher frequency then the signal on the horizontal deflection plates. Decrease the setting of the signal generator to one-half your recorded reading. You should now see a presentation similar to (B) below, indicating a 1:2 ratio. Now decrease the signal generator setting to one-third your recorded frequency. The scope presentation should now resemble (C) below, indicating a 1:3 ratio.



38.—Frequency Comparison-Lissajous Patterns.

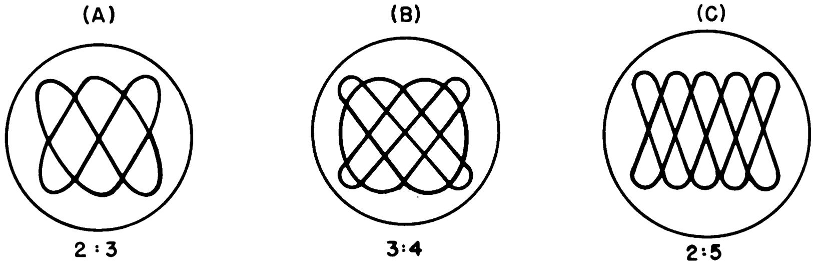
Experiment 6-4—Frequency Measurement Using an Oscilloscope (Continued)

By analyzing what you have observed thus far, it should be apparent that the number of loops in the Lissajous pattern and the position in which they lie can tell you a good deal. It is obvious that the ratio of the number of loops counted vertically to the loops counted horizontally gives the ratio of the two frequencies. Remember, the loops counted vertically represent the signal on the HORIZONTAL deflection plates, the loops counted horizontally across the scope represent the signal applied to the VERTICAL deflection plates. Thus in (A) below we have:

Oscillator frequency 2
Signal generator frequency 3 .66 X

Oscillator frequency .66 X Signal generator frequency

Since it is nearly impossible to completely stop these patterns on the scope, extreme care must be used in counting the number of loops.



39.—Lissajous Patterns.

Review

In this topic you have studied the general purpose oscilloscope.

The principal points you should have learned are listed below.

1. How the horizontal sweep circuit causes the beam to sweep across the face of the CRT.
2. How the sweep time is controlled either internally or by an external trigger.
3. The names and functions of the front panel controls and input connections of a typical general purpose oscilloscope.
4. How Lissajous patterns are developed and how to interpret them.
5. The use of the graticule for amplitude and time measurement of waveforms.

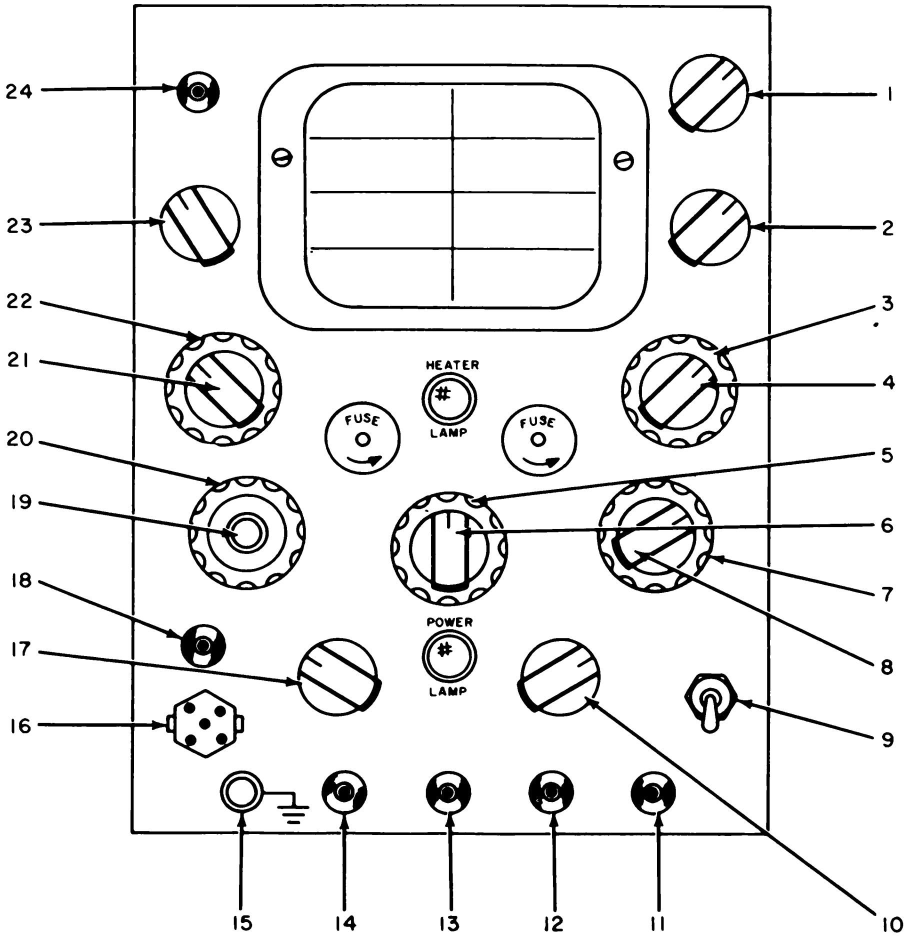
TOPIC 7: SYNCHROSCOPE, AN/ USM-32

The AN/ USM-32 is found throughout the fleet and is somewhat more refined than scopes you have been using this far.

The AN/ USM 32, in addition to the function of a basic scope, incorporates circuits which make it possible to measure frequency or voltage without the use of other test equipment.

These same functions are available at output jacks for use in other test equipment.

A list of the front panel controls and their functions follows.



40. —AN/ USM-32, Front Panel Controls.

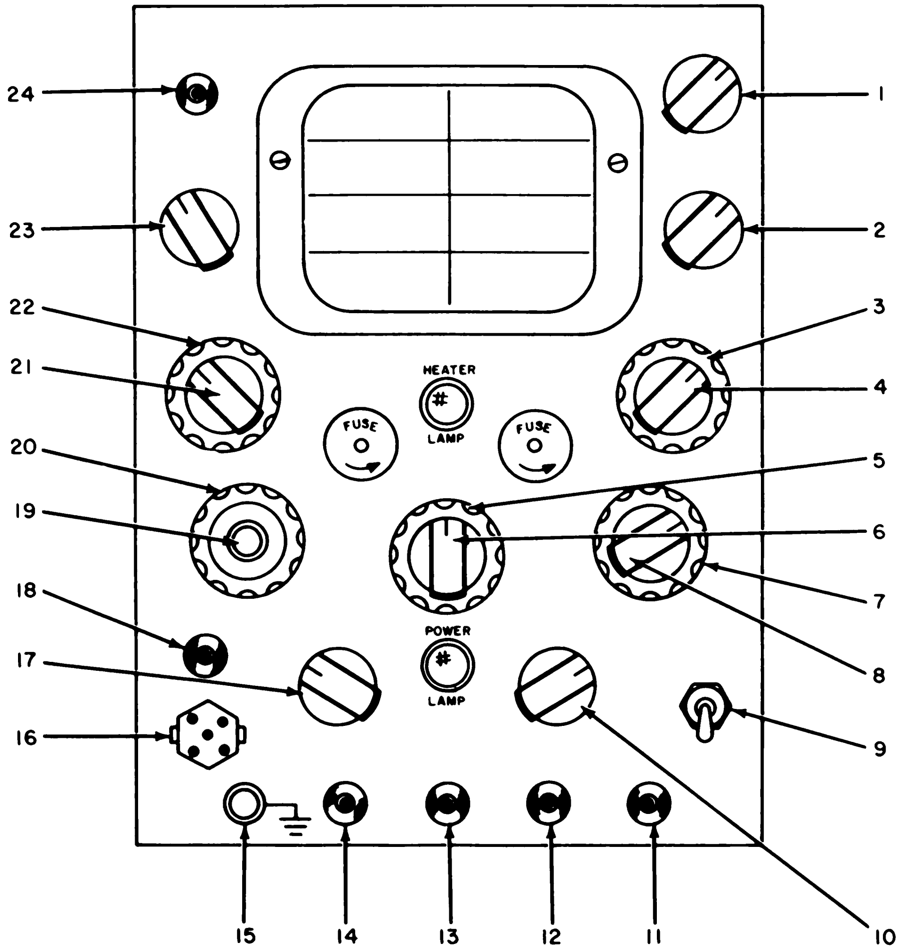
NAME	NO.	FUNCTION
BRIGHTNESS	1	Control; for adjusting brilliance of trace.

SYNCHROSCOPE, AN/ USM-32

NAME	NO.	FUNCTION
FOCUS	2	Control; to adjust for maximum sharpness of trace.
HOR GAIN	3&4	Concentric controls; outer knob-HORizontal GAIN-provides horizontal expansion of sweep trace; Inner knob-HORizontal POSition-provides horizontal positioning of trace.
SWEEP TIME	5&6	Concentric controls; outer knob-SWEEP TIME (COARSE)-provides step adjustment of sweep duration: inner knob-SWEEP TIME (FINE) -provides continuous control of sweep duration within limits established by SWEEP TIME (COARSE) setting.
SYNCHRONIZATION (SELECTOR-GAIN)	7&8	Concentric controls; outer knob selects source and polarity of sweep initiating signal from TRIGger, power LINE frequency, EXternal signal, EXternal attenuated 15:1, and vertical amplifier; inner knob continuously controls sync amplitude.
POWER ON-HEATER ON	9	Toggle switch; for applying primary power for operation of either the instrument or the space heater.
MARKER INTERVAL	10	Control switch for selection of internal timing markers or external timing signals, as desired.
SYNC IN	11	Coaxial terminal jack; for connecting external sweep initiating signals, 1 meg, 45uuf (EX) 1.5 meg, 10uuf (EX/ 15).
MARK OUT; Z IN	12	Coaxial terminal jack; dual function as selected by MARKER INTERVAL switch-(1) Supplies intensity markers for external use or (2) provides input connection for external timing signals.
CAL OUT; 0.6 VPP	13	Coaxial terminal jack; supplies CALibration OUTput signal of 0.6 volt peak-to-peak for external use.

SYNCHROSCOPE, AN/ USM-32

NAME	NO.	FUNCTION
+ TRIG OUT	14	Coaxial terminal jack; supplies positive trigger pulses of approx. 100v for external use at a repetition rate determined by setting of TRIGGER RATE control.
GND	15	Binding post terminal; provides a connection for grounding the instrument.
C. F. PROBE	16	Terminal socket; dual function of connection of (1) Cathode-Follower PROBE or (2) 75-ohm TERMINATION for the VERTical SIGnal.



41. —AN/ USM-32, Front Panel Controls.

SYNCHROSCOPE, AN/ USM-32

NAME	NO.	FUNCTION
TRIGGER RATE	17	Control with switch; ON-OFF switch operates internal trigger generator. TRIGGER RATE control provides continuous adjustment of repetition rate.
VERT SIG	18	Coaxial terminal jack; for connection of input signal to vertical amplifier. Impedance 1 meg, 28 uuf.
PRESS TO CAL, VOLTS PER INCH	19&20	Concentric switches; outer knob-volts per inch-provides accurate-ratio step attenuation of input signal: inner button- PRESS TO CALibrate-used in conjunction with VERTical GAIN for amplifier calibration. Set to 2" for indicated sensitivities.
VERT POS, VERT GAIN	21&22	Concentric controls; outer knob-VERTical GAIN- provides continuous amplitude adjustment of vertical deflection. (Also used to set vertical amplifier to known sensitivity for amplitude calibration); inner knob VERTical POSition provides vertical positioning of trace.
VERT DIRECT-AMP	23	Control switch; for selection of "through vertical amplifier" or "direct to deflection plate" connection of input signal.
VERT DIRECT	24	Coaxial terminal jack; for connection of input signal through a capacitor direct to a deflection plate 3 meg, 30 uuf.

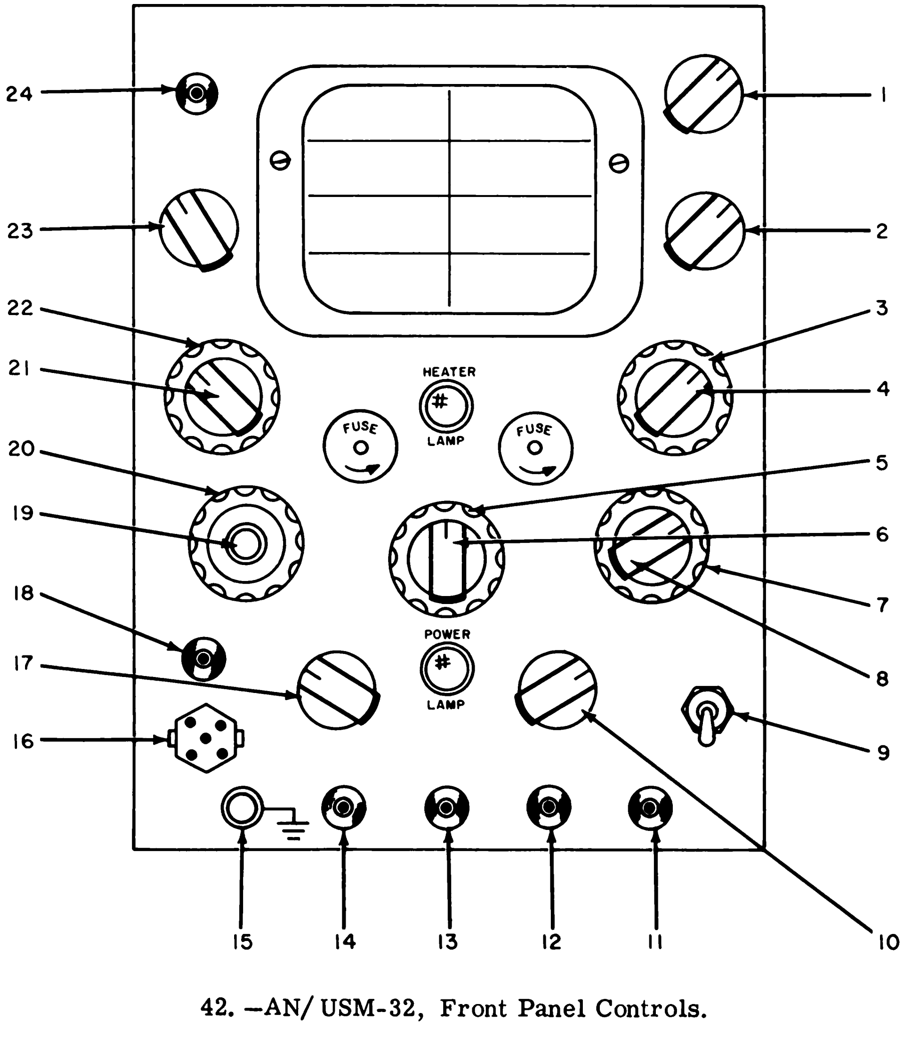
Functional Description

Before using the AN/ USM-32 it will be to your advantage to understand the over-all operation and internal signal flow of the scope. The following discussion is designed to give you a better understanding of the scope. Refer to AN/ USM-32, pages B7-B8 for location of the components under discussion.

The vertical signal can be applied to the scope in one of three different ways. If the signal is applied to the VERT. DIRECT jack and the VERT. DIRECT AMP switch is in the DIRECT position, the signal is applied directly to the vertical plate of the CRT. If the signal is applied to the VERT. SIG. jack with the VOLTS-PER-INCH switch in the CF PROBE position and the CF PROBE plugged in, the signal bypasses the vertical

Functional Description (Continued)

attenuator but goes through the amplifier. The normal input is to the VERT. SIG. jack with the VOLTS-PER-INCH switch in one of the attenuator positions. In this case the signal is attenuated and then sent to the vertical amplifier. The VERTICAL GAIN control is in this circuit. After the first amplification, a portion of the signal is sent back to the sync circuits to aid in synchronizing the sweep. The signal is also sent to the delay line where it is delayed slightly to allow the sweep to start before the signal is applied to the sweep. From the delay line, the signal is sent to the vert. deflection amplifier where it is further amplified and inverted to produce two signals 180 degrees out of phase to be applied to the vertical plates of the CRT. The VERTICAL POSITION control is in the final stage.



42. —AN/ USM-32, Front Panel Controls.

Functional Description (Continued)

Also incorporated in the vertical section is the voltage calibrator. This circuit provides a calibrated 0.6v peak-to-peak 60 cycle square wave voltage for calibration of the scope when the PRESS-TO-CAL. button is pushed in. This same voltage is available for external use at the CAL. OUT jack. It is also sent to the SYNC SELECTOR switch for synchronization of the sweep when the switch is in the LINE position.

The horizontal section actually originates at the sync circuit. The sync circuit may be triggered from four sources either positively or negatively depending upon the position of the SYNC SELECTOR switch. When this switch is in the "V" position, the trigger is fed back from the vertical amplifier. When the switch is in the LINE position the trigger is supplied by the .6V peak-to-peak square wave from the voltage calibrator. When the switch is in the EX position, the trigger may be applied from an external source connected to the SYNC IN jack. This external signal may also be attenuated 15:1 by setting the SYNC SELECTOR switch to EX/15. When the SYNC SELECTOR switch is in the TRIG position the trigger is applied from the Trigger Generator. The frequency of the trigger can be varied from 45 cps to 5500 cps by rotation of the TRIGGER RATE CONTROL switch in the Trigger Generator circuit. This trigger is also available at the TRIGGER OUT jack for external use.

After the desired trigger has been applied to the sync circuit, the amplitude of this signal can be controlled by the SYNC GAIN control. The signal is then coupled, either negatively or positively, depending on the setting of the SYNC SELECTOR switch, to the Gate Generator.

The Gate Generator is a multivibrator which provides a square wave when triggered. This square wave is used to trigger the three circuits that follow it. These are the Sweep Generator, Gate Shaper and the Time Mark Generator. We will discuss these circuits separately.

The Sweep Generator, when triggered by the Gate Generator, initiates a sawtooth voltage. The frequency of the sawtooth is controlled by the setting of the COARSE and FINE SWEEP TIME control. The output of the Sweep Generator is coupled to the Sweep Deflection Amplifier where it is amplified and inverted to provide two sawtooth voltages 180 degrees out of phase, to apply to the horizontal plates of the CRT. The HORIZONTAL GAIN and HORIZONTAL POSITION controls are also in this final stage.

The square wave signal applied to the Gate Shaper is reshaped and applied to the control grid of the CRT as unblanking voltages. The CRT is normally in a cut-off condition and therefore must be unblanked during sweep time.

The square wave signal applied to the Time Mark Generator activates an extremely accurate oscillator. The output of this oscillator is shaped into pulses at very accurate time intervals in microseconds of 1, 10, 100, 1,000, or 10,000, determined by the setting of the MARKER INTERVAL control. When the MARKER INTERVAL control is in any of these positions, the markers are sent to the Beam Modulation Amplifier and are also

Functional Description (Continued)

available at the MARK OUT-Z IN jack for external use. The Beam Modulation Amplifier, after amplifying the markers, sends them to the cathode of the CRT where they are applied as positive spikes to cut the CRT off each time a marker is applied. These markers will then appear as dark spots on the sweep. The intervals between the dark spots are a definite number of microseconds wide depending on the setting of the MARKER INTERVAL switch.

Another possible input to the Beam Modulation Amplifier can be accomplished by setting the MARKER INTERVAL switch to Z IN. In this position an external marker can be applied at the MARK OUT-Z IN jack to provide the markers on the scope. A positive 10 volt peak pulse will provide blanking or dark spots on the sweep. A negative 10 volts peak pulse will provide bright spots on the sweep. When using the Z IN marker the scope sweep must be synchronized externally to the frequency of the Z-IN signal.

Included in the scope is a space heater that may be used to keep the scope warm when it is not actually being used. This is accomplished by setting the power switch to the "Heater On" position.

The scope contains its own high and low DC voltage and AC voltage power supplies that are necessary for operation when 115 VAC signal phase, 60 cycle power is applied and the power switch is in the POWER ON position.

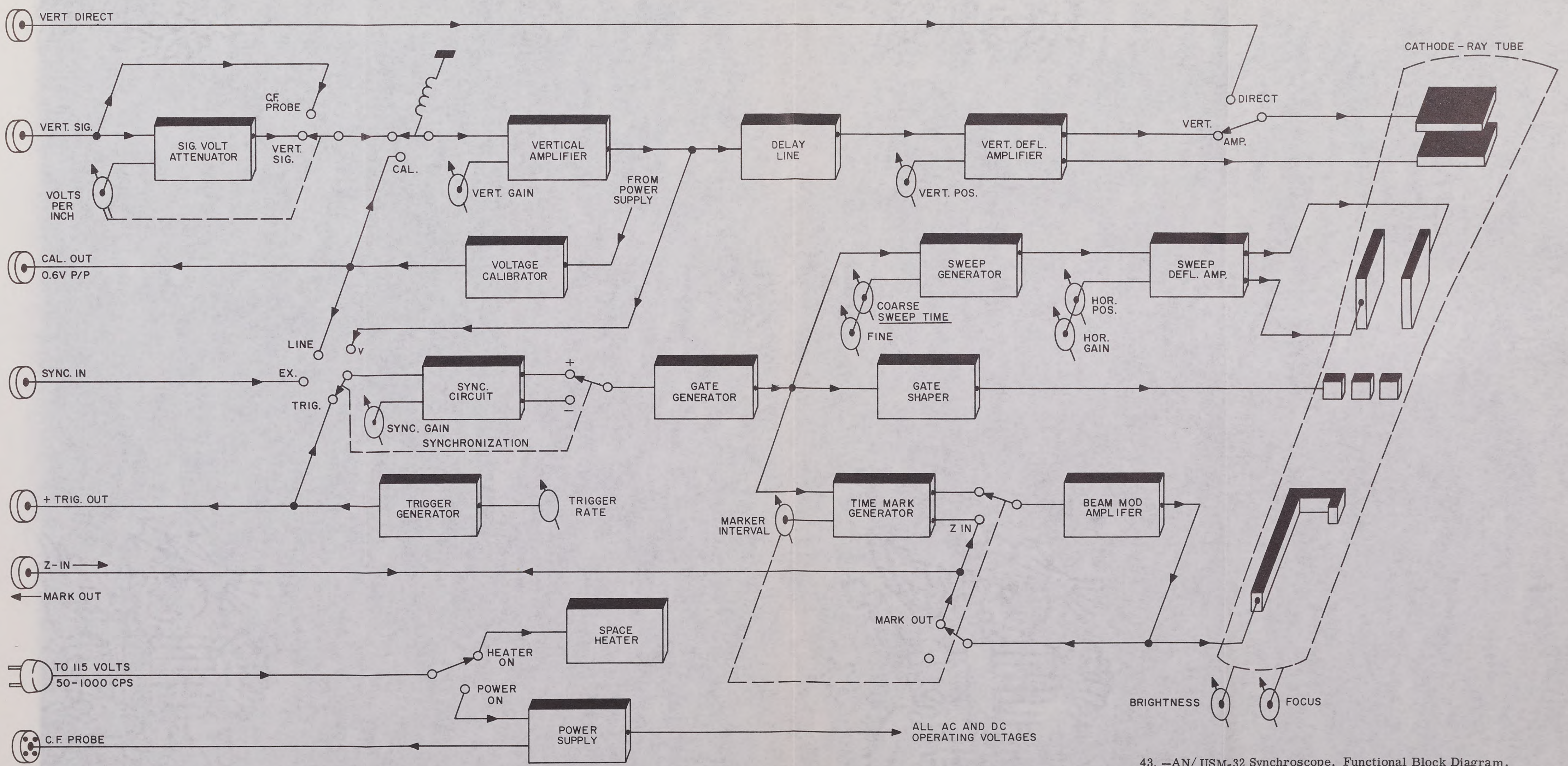
Information on theory, operation, care, and maintenance of the AN/USM-32 is contained in INSTRUCTION BOOK, NAVSHIPS 92257.

Experiment 7-1—Frequency and Voltage Measurement

Observing wave form and checking Frequency and Voltage using the AN/USM-32.

The AN/USM-32 is designed so that a waveform may be observed and it's frequency and voltage measured in one continuous operation without the use of other test equipment. To illustrate this, perform the following experiment. Refer to page 64 of this publication to locate controls.

The following set-up is a basic set-up that can normally be used, with minor variations, when using the scope. With the POWER switch (9) in the HEATER-ON position,. plug in the line cord. The HEATER lamp should light. Throw the switch to POWER ON. The POWER lamp should light. Allow at least one minute warm up time. Set the TRIGGER RATE switch (17) to OFF, MARKER INTERVAL (10) to Z IN. Since you will be using external synchronization, set the SYNC SELECTOR switch (7) to +EX and SYNC GAIN (8) to mid scale. Set SWEEP TIME COARSE (5) to 20K-2K and FINE (6) to mid scale. Set the VERT-DIRECT-AMP switch (23) to AMP, adjust BRIGHTNESS (1) and FOCUS (2) for a clear sweep. Adjust HORIZONTAL POSITION (4) and VERTICAL POSITION (21) as necessary to center the sweep on the scope. Set the VOLTS-PER-INCH switch (20) on 30. You are now set up to connect the scope to



43. —AN/ USM-32 Synchroscope, Functional Block Diagram.

Experiment 7-1—Frequency and Voltage Measurement (Continued)

the Wien Bridge Oscillator. Refer to NAVPERS 92213A Vol. 1 page 29 for setup of Wien Bridge Oscillator.

Connect a lead from the ground terminal (15) to chassis ground. Connect a lead from the VERT. SIG-jack to the plate pin 5 of V2B (A-8R). Connect a lead from the SYNC IN jack to the cathode, pin 6 of V2B (A6L). A signal should appear on the scope. Adjust the FINE SWEEP TIME to stabilize the signal. It may also be necessary to adjust SYNC GAIN (8). Observe the signal and adjust VERT. GAIN (22) for best viewing. Adjust R4 and R7 as necessary to obtain a good sine wave output.

Next you will check the frequency of the Wien Bridge Oscillator. To do this, first adjust the VERTICAL GAIN so that the signal is approximately one inch high on the scope. Adjust HORIZONTAL GAIN or FINE SWEEP TIME or both if necessary, to obtain about two complete cycles on the scope. Set the MARKER INTERVAL switch to 100. Dark spots should appear on the sine wave. With this setting, the distance between the dark spots is 100 microseconds or .0001 seconds. Therefore, by counting the number of dark spots in one complete cycle, the time duration of that cycle can be determined and frequency can be calculated. (Assuming that there are 13 dark spots in one cycle, the time duration of that cycle would be 1300 microseconds or .0013 seconds. By dividing .0013 into 1 second you can determine cycles per second. In this case frequency would be about 769 cps.) Using this procedure, find the frequency of your Wien-Bridge Oscillator.

Next you will measure the peak-to-peak voltage of the Wien Bridge Oscillator output. In order to do this, the scope must first be calibrated to a known voltage, in this case the calibrator output. This is applied to the scope by pushing the spring loaded PRESS-TO-CAL button (19). Hold the button depressed and adjust the VERT. GAIN until the signal is 2 inches in height on the scope. (4 major divisions or 20 small squares.) Do not move the VERTICAL GAIN again during this check. When the button is released, and with the setting of the VOLTS-PER-INCH control on 30, each inch on the scope is equal to 30 volts and each small square is equal to 3 volts. With the output of the Wien Bridge applied to the scope, count the number of squares the sine wave covers vertically. (Assuming that it is 14 squares high, the peak-to-peak voltage would be 14 X 3 or 42 volts.) Using this procedure, check the amplitude of the output of your Wien Bridge Oscillator.

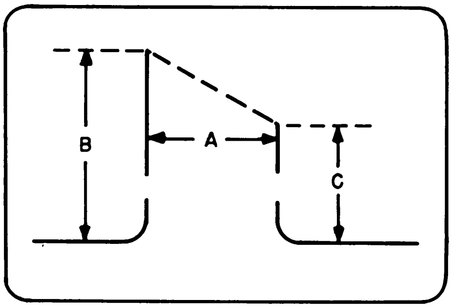
Experiment 7-2—Pulse Width and Amplitude Measurement

Many times, while troubleshooting equipment, it becomes necessary to completely analyze a waveform. You may wish to measure the width of a pulse and at the same time determine it's amplitude. To illustrate how this may be accomplished perform the following experiment. Refer to NAVPERS 92213A Vol. 1, pages 26 and 127.

Set up the scope in the Wien Bridge Oscillator experiment. Connect the SYNC IN jack to pin 6 of V2B (A6L). Set the SYNC SELECTOR switch

Experiment 7-2—Pulse Width and Amplitude Measurement (Continued)

on +EX. Connect a lead from the VERT SIG. jack to the cathode pin 6 of V6B (A-26L). Set the VOLTS-PER-INCH switch to 100. Connect a lead from the scope ground jack to chassis ground. Energize the chassis and adjust as necessary to obtain an output from the Blocking Oscillator. You may have to adjust SWEEP TIME (FINE) and SYNC AMP to get a steady sweep. After you have obtained a steady sweep, adjust HORIZONTAL GAIN and HORIZONTAL POSITION to obtain only one pulse on the screen. Your signal should be similar to the one shown below.



44. —Blocking Oscillator Output.

You will now measure the width of the pulse, time "A" as shown above. Set the MARKER INTERVAL switch to 100. Dark spots will appear on the sweep. The distance between these dark spots at this setting is 100 microseconds, spaced as they appear on the pulse. There should be about 4, therefore the pulse will be 4 x 100 or about 400 microseconds wide.

Another, and possibly more accurate method of determining the width of the pulse is as follows; select two of the marks (dark spots) that are on the horizontal section of the sweep. Adjust HORIZONTAL GAIN until there is exactly one square on the scope screen from the center of one mark to the center of the next mark. Do not change HORIZONTAL GAIN for the rest of this section of the experiment. You will then have adjusted the scope so that each horizontal square is equal to 100 microseconds. You can count the number of squares that the pulse covers horizontally and multiply this figure by 100 to determine the width of the pulse in microseconds. Using both of these methods determine the width of the output pulse of your Blocking Oscillator.

Next, you will measure the amplitude of the leading edge of the pulse. To accomplish this, the scope screen must be calibrated. Depress the PRESS-TO-CAL button and hold it depressed while you adjust SWEEP TIME to obtain several square waves on the scope. With the button still depressed, adjust the VERTICAL GAIN so that the square wave is two inches high (4 major divisions or 20 small squares). With the VOLTS-PER-INCH switch set on 100, when the button is released the scope will be calibrated for 100 volts per inch or 10 volts per square vertically. Release the button and adjust the VERTICAL POSITION so that the bottom

Experiment 7-2—Pulse Width and Amplitude Measurement (Continued)

of the pulse is on a horizontal line. Count the number of squares that the leading edge covers vertically. Since each square is equal to 10 volts, you can calculate the voltage by multiplying the number of squares by 10. Assuming that the pulse is 12 squares high, the amplitude is 12 x 10 or 120 volts. Using this procedure, measure the amplitude of the leading edge and the trailing edge of the output of the Blocking Oscillator on your chassis. Make a comparison to determine how much the voltage dropped from the leading edge until the start of the trailing edge (time "A"). By analyzing the information you can determine that the pulse is of proper width, amplitude, and shape.

Experiment 7-3—Multivibrator Output Adjustment

Many adjustments in electronics equipment involve adjusting a square wave to a definite width in microseconds. To illustrate how this can be accomplished using the AN/USM-32, perform the following experiment. Refer to NAVPERS 92213A Vol. I, page 147.

You will set the width of the positive portion of the square wave at the plate, pin 5 of V7B (B-14R) so that it is 800 microseconds wide.

Set up the scope according to the basic set up given in the experiment on the Wien Bridge Oscillator. Set the VOLTS-PER-INCH switch on 10Q. Connect a lead from the SYNC IN jack to the cathode, pin 6 of V2B (A-6L). Connect a lead from the VERTICAL SIGNAL jack to the plate, pin 5 of V7B (B-14R). Connect lead from the scopes GROUND jack to chassis ground. Energize the chassis and adjust SWEEP TIME, SYNC GAIN and HORIZONTAL GAIN to obtain one sweep on the scope. Adjust HORIZONTAL POSITION so that the positive portion of the wave is approximately in the center of the screen.

Set the MARKER INTERVAL switch to 100. Markers should appear on the square wave. Adjust HORIZONTAL GAIN so that there is exactly one square between the center of one marker and the center of the next marker. You have then calibrated the scope so that each square is 100 microseconds wide. Since you no longer need the markers and since the following adjustment will be easier without them, set the MARKER INTERVAL switch to Z IN.

Since each square is equal to 100 microseconds, all that remains to be done is to adjust the positive portion of the square wave so that it is 8 squares wide. Adjust R-27 in the One Shot Multivibrator to accomplish this. Your adjustment is then complete.

SYNCHROSCOPE, AN/ USM-32

Review

In this topic you have learned the use of the more advanced type oscilloscope, commonly called "synchroscope".

You have learned:

1. The names and functions of the front panel controls of the AN/ USM-32.
2. How the synchroscope differs from the general purpose oscilloscope; the additional circuits, functions and capabilities of the AN/ USM-32.
3. Where a synchroscope can be used to advantage.
4. Operation and purpose of the Time Mark Generator and Beam Modulation Amplifier.
5. How to use the AN/ USM-32 for pulse width and amplitude measurements and for making adjustments of pulse circuits.

TOPIC 8: SYNCHROSCOPE, AN/ USM-117

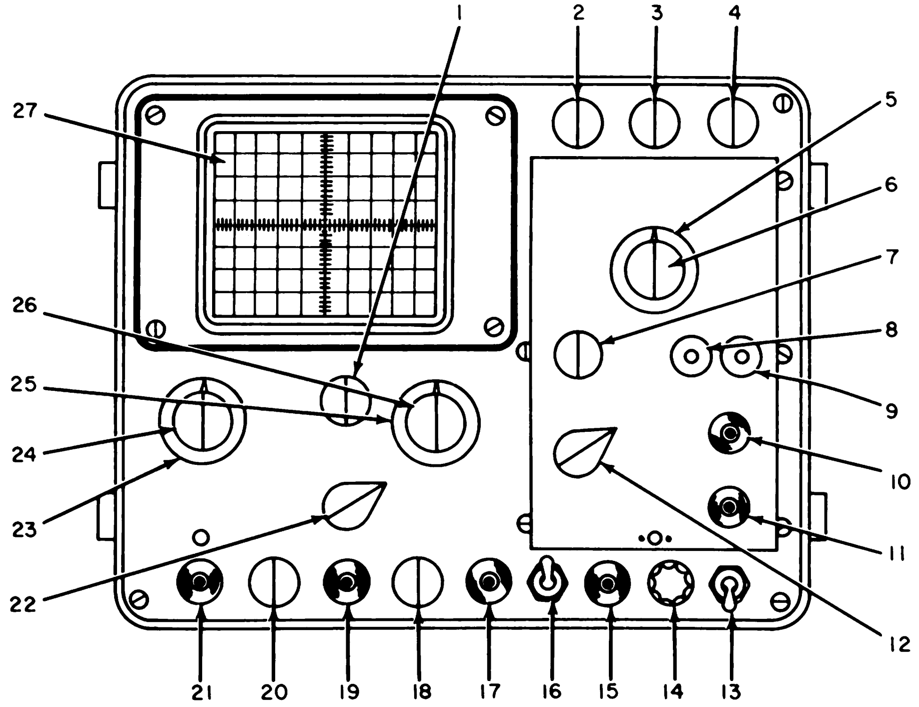
The theory and operation of the AN/ USM-117 synchroscope is fundamentally the same as the general purpose oscilloscope covered in the previous topic. However, the display obtained is more useful to the technician because it has a calibrated horizontal time base and a calibrated vertical deflection factor.

The oscilloscope display is a graphical presentation of instantaneous voltage versus time. To make this display more useful, the horizontal sweep can be deflected at a known, precise linear rate so that any given horizontal distance on the screen represents a definite known period of time. The calibrated time base of the AN/ USM-117 provides this feature.

The voltage amplitude of the input waveform can be accurately measured by the calibrated vertical deflection factor. This is easily accomplished by precision voltage attenuators in the pre-amp and a pre-set gain of the vertical amplifier. The attenuators provide a selection of volts/ division of the graticule.

Sine wave signals to near five mega-cycle frequency can be accurately measured by this transistorized, compact size, light weight, and portable oscilloscope.

These characteristics enable the maintenance technician to be more precise, thus more accurate when adjusting electronic equipments.



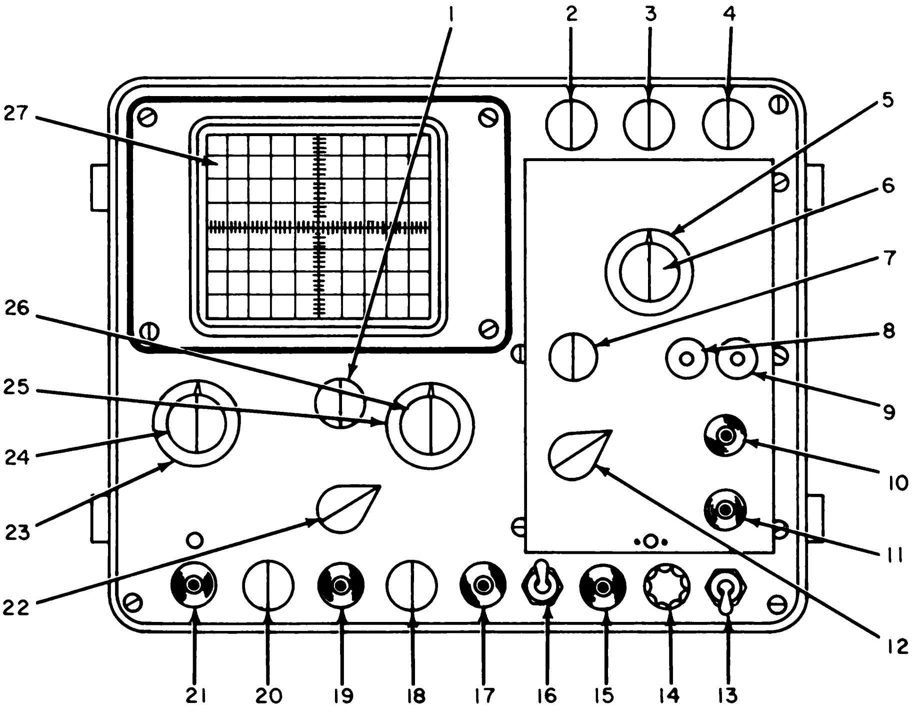
45. —AN/ USM-117, Front Panel.

SYNCHROSCOPE, AN/ USM-117

Now you are going to learn the operation of the AN/ USM-117. The first step is to study the location and function of the front panel controls. They are shown on the facing page and a brief description of each control follows:

NAME	NO.	FUNCTION
STABILITY	1	Adjusts the time base generator for TRIGGER (driven) operation or FREE RUN (recurrent) operation. PRESET position provides optimum triggering point as determined by an internal stability control.
INTENSITY	2	Adjusts the degree of spot or trace brightness.
FOCUS	3	Adjusts size and sharpness of spot on CRT screen.
ASTIG	4	Adjusts shape of spot on CRT screen.
VOLTS/ DIV switch	5	Selects Vertical deflection sensitivity values from 0. 01 volt to 20 volts peak-to-peak per division. AC coupled only below 0. 1 volt per division.
VARIABLE control	6	Concentric red knob with VOLTS/ DIV switch provides uncalibrated variable sensitivity between steps on the VOLTS/ DIV switch. Also extends sensitivity on 20 VOLTS/ DIV range to 50 VOLTS/ DIV.
POSITION control	7	Positions the trace on a vertical plane.
DC BAL control	8	Adjusts balance of vertical preamplifier, thereby preventing trace shift when the variable control is rotated.
EF BAL control	9	Adjusts input impedance of input stage to proper value, and prevents trace shift when VOLTS/ DIV switch is rotated.
INPUT A connector	10	Accepts signals fed to vertical preamplifier.

NAME	NO.	FUNCTION
INPUT B connector	11	Accepts signals fed to vertical preamplifier.
INPUT SELECTOR switch	12	Selects either INPUT A or INPUT B with AC or DC coupling as desired.
POWER switch	13	Turns power on or off.
SCALE control	14	Adjusts illumination of lines on the CRT graticule.
CALIBRATOR OUTPUT	15	Provides accurate square wave of either 0. 04 or 0. 4 volts, P-P, as determined by the setting of the CALIBRATOR switch.
CALIBRATOR switch	16	Selects accurate square wave of either 0. 04 or 0. 4 volt, P-P. Output waveform is available at front panel jack.



46. —AN/ USM-117 Front Panel.

NAME	NO.	FUNCTION
EXT TRIGGER INPUT connector	17	Accepts signals to trigger the sweep when the TRIGGER SLOPE switch is set to any position on the right hand side of its dial.
POSITION control	18	Positions the trace on a horizontal plane.
HORIZONTAL INPUT connector	19	Accepts signals for horizontal deflection when the HORIZONTAL MODE switch is set to X1, X2 or X5.
HORIZONTAL GAIN control	20	Adjusts uncalibrated variable sensitivity between X1, X2 and X5b ranges. Also extends sensitivity on X5 range beyond five volts per division.
Z-AXIS INPUT connector	21	Accepts signals for intensity modulation of CRT.
HORIZONTAL MODE switch	22	Functions to attenuate external horizontal deflection waveforms on the X1, X2 and X5 positions. Also provides sweep and 5X MAG sweep.
TIME/ DIV switch	23	Selects sweep speeds in 19 calibrated steps in a 1, 2, 5 or 10 sequence from 0. 1 microsecond to 0. 1 second per division.
VARIABLE control	24	Concentric red knob with TIME/ DIV switch provides adjustment between steps on TIME/ DIV switch. When turned from the maximum CW position, the sweep is uncalibrated.
TRIGGER SLOPE switch	25	Selects the type of triggering signal; LINE, INT, and EXT on either + or—slope. AC or DC coupling may be selected on EXT TRIGGER INPUT.
LEVEL control	26	Concentric red knob with TRIGGER SLOPE switch determines the level of the amplitude of the triggering waveform for the start of the sweep.
GRATICULE	27	Edge illuminated type, 10 divisions long by 8 div. high. (1 division equals 1/ 4 in.)

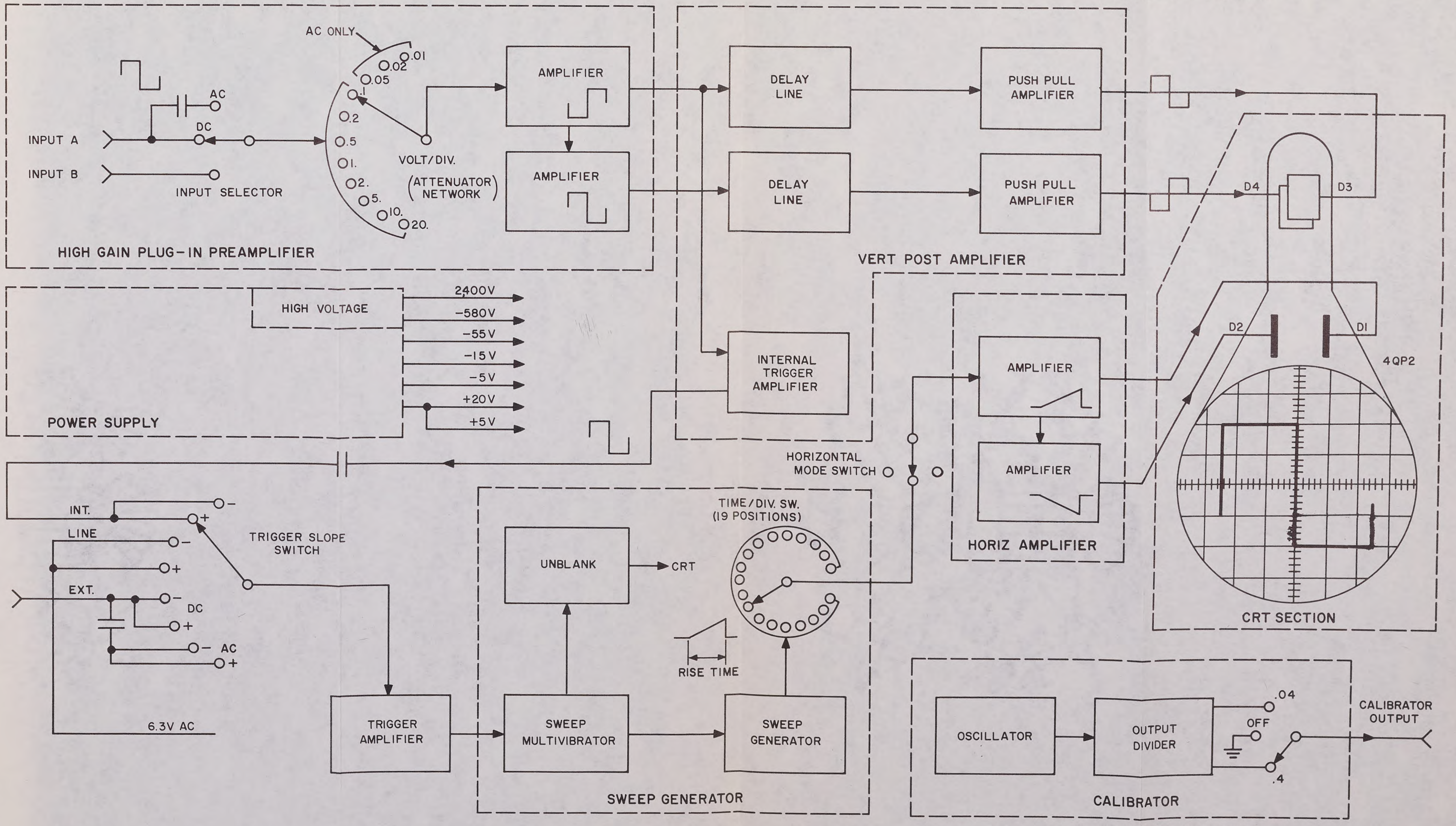
Power Requirements:	Designed to operate from a power source of 115 VAC, 60 or 400 cps, at 25 watts or more. It is important that the Power Cable be plugged into a properly grounded three connector power receptacle which matches the three prong polarized plug. WARNING—A shock hazard will result if the green (ground) lead is not properly grounded.

The functional operation of the internal circuitry of the AN/USM-117 Synchroscope can be attained by studying the block diagram shown on page 79. The signal flow starts with a signal being applied to the test probe. Let us take the .4 Volt P-P output of the scope's calibrator as a signal to INPUT A, thus the INPUT SELECTOR must be in position A for the square wave to reach the VOLTS/DIV switch. The VOLTS/DIV switch has eleven positions ranging from .01 Volt to .05 Volt (P-P)/DIV AC and .1 to 20 Volt P-P AC or DC. One of the eleven attenuator networks is selected and the square wave is now applied to the preamplifier. The several stages of paraphase amplifiers produce a balanced push pull output. (Two signals, 180^{o} out of phase, of equal amplitude.) The above circuits are all contained in a high gain "plug-in" preamplifier.

The balanced push pull square wave signal is now applied to the delay lines of the vertical amp section. These delay lines cause a delay in time of the start of the balanced push pull signal. This delay insures that the horizontal time base starts before the signal, when the internal trigger is used. The entire signal may be observed on the CRT under this selected condition.

The square wave signals are next applied to the vertical amplifier stages. These push pull amplifiers enlarge the voltages sufficiently to cause CRT beam deflection and are applied to the vertical deflection plates. The gain of the vertical amplifier is of a fixed value when the VARIABLE control is turned maximum clockwise to the calibrate position.

Observe the input signals to the vertical amplifier again and notice that one signal, before going to the delay line, is also coupled to the internal trigger amplifier. This signal after being amplified, is in phase with the original square wave at the test probe. It is sent to the TRIGGER SLOPE switch which has four positions. These are: INT (internal), LINE, EXT-AC (external), and EXT-DC. A selection of positive or negative slope triggering can be made for each position. The selected trigger is sent to the trigger amplifier and is then coupled to the sweep multivibrator as its trigger. One output of the driven sweep multivibrator is applied to the unblanking circuits. The unblanking circuits apply a positive square wave to the control grid to increase beam intensity for the time occurrence of the horizontal sweep. The other output of the sweep multivibrator is coupled to the sweep generator. The sweep generator developes a linear sawtooth wave form of a constant amplitude. The RC time network



47. —AN/ USM-117 Block Diagram

controlling the rise time of the saw tooth wave form is selected by the TIME/DIV switch. Any one of nineteen calibrated sweep speeds can be selected when the VARIABLE control is maximum clockwise. The time/division selection range is from .1 micro sec/div to .1 sec/division.

The selected sweep rate saw tooth wave form is sent from the TIME/DIV switch to the horizontal amplifier. The horizontal amplifier inverts and amplifies the single saw tooth wave form, thus balanced-push pull saw tooth wave forms are used to drive the horizontal deflection plates of the CRT.

It is possible to apply an external signal directly to the horizontal amplifier through the HORIZONTAL MODE switch. The HORIZONTAL MODE switch also provides a 5X magnification factor in the calibrated position. The 5X magnification adds microscopic precision to the synchroscope.

The calibrator shown provides two calibrated square wave outputs for external use. The .4 Volt P-P or .04 Volt P-P output can be selected with the CALIBRATOR switch. The CALIBRATOR ON-OFF switch allows it to be off when not in use.

The .4 Volt P-P output of the calibrator was used as a signal input in the block diagram. With the VOLTS/DIV switch to .1 position and VARIABLE control maximum CW, the CRT display should be a square wave having a P-P amplitude of 4 divisions. This illustrates a check of the gain of the vertical amplifier section.

If the output of the calibrator were 1000 cycles/sec and .2 millisec/div is selected in the CALIBRATE position the period of the square wave will extend over 5 divisions horizontally.

The AN/USM-117 has its own power supply unit. The low voltage power supply provides regulated DC voltages of 55V, -15V, -5V, +5V and +20V. The high voltage power supply provides a 2400 VDC and -580 VDC for the CRT.

You will use the synchroscope to perform experiments that require measuring waveform amplitude and time duration.

Experiment 8-1—AN/USM-117 Checking Voltage Calibration

The AN/USM-117 provides a highly accurate calibrated square wave output at the CALIBRATOR jack either .04 or .4 volts peak-to-peak to be used for voltage calibration of equipment. It can also be used to check the accuracy of the settings of the VOLTS/DIV switch.

To accomplish this, connect a lead from the calibrator output (15) to INPUT A. Set the VOLTS/DIV switch to .01 and the Variable VOLTS/DIV control maximum clockwise. Set the CALIBRATOR switch to .04. The square wave on the scope should be exactly 4 squares high ±5%. Set the VOLTS/DIV switch to .02. The square wave should now be two squares high.

Experiment 8-1—AN/ USM-117 Checking Voltage Calibration (Continued)

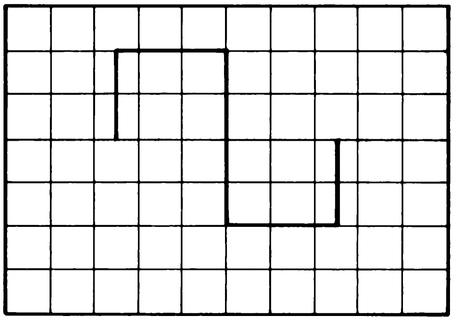
Set the VOLTS/DIV switch to . 1 and the CALIBRATOR switch to . 4. The square wave should be 4 squares high. Set the VOLTS/DIV switch to . 2. The square wave should now be 2 squares high.

If these checks result in proper reading, the scope voltage reading can be considered as accurate; if not, the scope must be recalibrated and adjusted. These adjustments must be made only by experienced personnel according to directions in NAVSHIPS 94344(A).

Experiment 8-2—Frequency and Voltage Measurement

The waveform can be observed, the frequency determined, and the voltage measured in one operation using the AN/ USM-117.

The method of determining the frequency, used in this experiment, is to measure the period of one cycle and calculate the frequency by use of the formula f=1/ P. This is an accurate and widely used method.



SWEEP CALIBRATION: .2 ms/DIV

VERT CALIBRATION: .1 V P-P/DIV

48. —Method of Determining Frequency.

The horizontal sweep of the AN/ USM-117 is calibrated to represent an exact time in microseconds or milliseconds. Shown above, the horizontal sweep is adjusted so that each square on the graticule is equal to . 2 milliseconds. One cycle of the input waveform covers 5 squares, thus 5 x . 2 x 10^{-3} = . 001 sec, or 1 millisecond. This is the PERIOD of one cycle. The frequency equals 1/ P or 1000 cps.

The voltage is measured by applying the input signal to a calibrated vertical amplifier. Adjusting the VOLTS/ DIV selector and the VARIABLE control allows a known P-P voltage to cover a set number of squares on the graticule. Shown above, each square is equal to . 1 volt P-P. When a signal waveform applied to the vertical input covers 4 squares along the Y axis, the voltage is 4 x . 1 or . 4 volts P-P. Peak voltage then is . 2 volts. The RMS value of a sine wave can be found by multiplying peak voltage x . 707.

Experiment 8-2—Frequency and Voltage Measurement (Continued)

Refer to NAVPERS 92213A Vol. 1 page 29 for set up of Wien Bridge. Make basic set-up of AN/USM-117. (Refer to Exp. II-2-3.) To connect a signal from the Wien Bridge Oscillator to the scope, connect an adapter UG-1035/U to INPUT "A" jack. This adapter allows the use of ordinary test leads for connecting the signal. Set the INPUT Selector switch to INPUT AC. Set the VOLTS/DIV switch to 20. Connect a test lead from the red side of the adapter to the plate (pin 5) of V2B (A-8R). Connect a test lead from the black side of the adapter to chassis ground.

To apply external synchronization, connect another adapter UG-1035/U to the EXTERNAL TRIGGER jack. Connect the red side of the adapter to the cathode (pin 6) of V2B (A-6L) and black side to chassis ground. Set the TRIGGER SLOPE switch to +AC.

A signal waveform should now be visible on the scope. Set the TIME/DIV switch to .2 milli-sec. Turn the VARIABLE TIME/DIV control maximum clockwise. The sweep is now calibrated to equal .2 milli-sec. for each horizontal square on the graticule. Adjust the STABILITY and LEVEL controls as necessary to stabilize the signal. (Note: It may be necessary to adjust the Wien Bridge Oscillator to obtain a good sine wave output.) Count the number of squares one cycle covers (X-axis).

Observe the waveform and determine the period. Next, calculate the frequency. (Note: Do not move the VARIABLE TIME/DIV control as this will cause the sweep to lose calibration.)

Find the peak-to-peak voltage of the Wien Bridge Oscillator output. Set the VOLTS/DIV control to 10. Set the VARIABLE VOLTS/DIV maximum clockwise. The scope is now calibrated for 10V (P-P) for each vertical square. Adjust the vertical POSITION control to place the lower extremity of the sine wave exactly on a horizontal line. Adjust the horizontal POSITION control to place the top of the sine wave exactly on the center vertical line of the graticule. Count the number of squares the sine wave covers vertically, multiply this number by 10 V (P-P) to obtain the peak-to-peak voltage of the sine wave. Dividing by 2 gives the peak Voltage. Peak voltage times .707 gives RMS (effective) voltage. (Note: Do not move the VARIABLE VOLTS/DIV control as this will change the calibration.)

Experiment 8-3—Measuring Pulse Width and Amplitude

Many times, while troubleshooting radar equipment, it becomes necessary to determine the width of a pulse in microseconds and the amplitude of the waveform. To illustrate how this can be accomplished with the AN/USM-117, you will measure the width and amplitude of the output pulse at the cathode of the Blocking Oscillator. Refer to page 127 of NAVPERS 92213A Vol. 1.

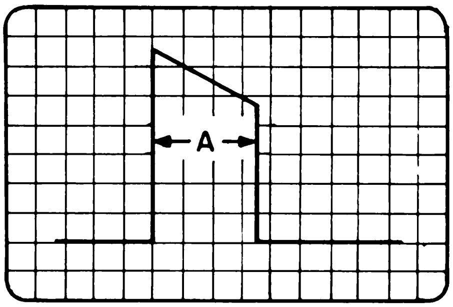
Experiment 8-3—Measuring Pulse Width and Amplitude (Continued)

Set the AN/USM-117 up as follows. Connect the red side of the EXTERNAL TRIGGER jack adapter to the cathode pin 6 of V6B (A-26L). Connect the black sides of both adapters to chassis ground. Adjust scope for a waveform similar to that shown below.

You may now measure the width of the pulse along line "A". To accomplish this, set the TIME/DIV control to . 1 milliseconds. Set the VARIABLE TIME/DIV control maximum clockwise.

The sweep is now calibrated for . 1 milliseconds or 100 microseconds for each horizontal square. Adjust the VERTICAL POSITION control so that the top of the trailing edge of the wave form is on the horizontal axis. Determine the number of horizontal squares that time A covers on the axis. The width in microseconds can be determined by multiplying this figure times 100 microseconds.

Assume that time A covers 3.4 squares. The width of the pulse at time A then is 3.4 times 100 microseconds or 340 microseconds. Using this procedure determine the width of the pulse on your Blocking Oscillator.



HORIZONTAL SWEEP
CALIBRATED EACH SQUARE = 100μs (.1 millisec)

49. —Blocking Oscillator Output.

Next you will check the amplitude of the leading edge of the pulse. To accomplish this, set the VOLTA/DIV switch on 20, and set the VARIABLE VOLTS/DIV control maximum clockwise and leave it there. Adjust the VERTICAL POSITION control so that the bottom of the pulse is on the lower horizontal line. Adjust the HORIZONTAL POSITION control so the top of the leading edge is on the vertical axis.

Count the number of squares that the leading edge covers vertically. Multiply this times the setting of the VOLTS/DIV switch to determine the amplitude. Assuming that the leading edge covers 6 squares, the amplitude would be 6 times 20 or 120 volts. Using this procedure measure the amplitude of both the leading and trailing edge of the pulse and make a

Experiment 8-3—Measuring Pulse Width and Amplitude (Continued)

comparison. By analyzing these readings you can determine that this pulse is being generated properly.

Experiment 8-4—Lissajous Patterns

The AN/USM-117 is very easily adapted for applying Lissajous patterns. It requires only the setting of the HORIZONTAL MODE switch to the X1, X2, or X5 position, depending on the amplitude of the input, and connecting the horizontal input signal to the HORIZONTAL INPUT jack (19) through the UG-1035/U adapter. The horizontal gain can also be controlled with the HORIZONTAL GAIN adjust (20).

Basic Set-Up for AN/USM-117. Plug in power cord to 115 VAC, 1 ϕ, 60 CPS. Place POWER switch to ON. Allow five minutes warm up time. Adjust the INTENSITY, FOCUS, and ASTIG for a clear sharp line on the CRT. Adjust the vertical POSITION and horizontal POSITION to center the sweep. Adjust the SCALE control to scale lines for best viewing. Set HORIZONTAL MODE switch to sweep. This set up is made each time the scope is used.

Refer to NAVPERS 92213A Vol. 1, pages 26 and 27, for experiment set-up. Set the VOLTS/DIV switch at 20 and apply the output of the Wien Bridge Oscillator to the INPUT A jack on the scope. Connect the 6.3 VAC filament supply from terminal 6 and 8 of T1 (Chassis) to the HORIZONTAL INPUT jack (19), through UG-1035/U.

Set the HORIZONTAL MODE switch to X1. Set the HORIZONTAL GAIN control so the signal is about 8 squares wide. Adjust R4 (on Chassis) until the signal stops or rotates very slowly. Count the number of loops horizontally. There should be approximately 12. There should be one loop vertically. Since the one vertical loop is caused by a 60 cycle signal and the ratio of loops is 1:12, the approximate frequency of the Wien Bridge Oscillator can be determined by multiplying 60 x 12. The frequency in this case is 720 cps.

Use this procedure and check the frequency of your Wien Bridge Oscillator.

Experiment 8-5—Adjusting Width of Multivibrator Output

Many adjustments in electronic equipment involves adjusting a square wave to a definite width in microseconds. To illustrate how this may be done, using the AN/ USM-117, perform the following experiment. Refer to NAVPERS 92213A Vol. 1, page 148.

You will adjust the positive portion of the square wave output at the plate, pin 5 of V7B (B-14R) so that it is 800 microseconds wide.

Connect the red side of the INPUT A adapter to (B-14R). Connect the black side to chassis ground. Calibrate the sweep by setting the TIME/DIV switch on .2 millisecond and the VARIABLE TIME/DIV maximum clockwise. The scope is now calibrated so that each horizontal square represents 200 microseconds.

In order for the square wave to be 800 microseconds wide, it must therefore cover 4 squares horizontally on the scope. Adjust R27 until the positive portion of the square wave covers 4 squares horizontally on the scope. The adjustment is then complete.

Review

In this topic you have studied the operation, capabilities and uses of the AN/ USM-117 synchroscope.

The principal points you should have learned are listed below.

1. Names and function of the front panel controls.
2. Signal flow from test probe to vertical deflection plates.
3. Horizontal sweep generation, calibration and flow to the horizontal deflection plates.
4. Function and use of the Calibrator.
5. Operation and outputs of the Power Supply Unit.
6. How to check voltage calibration.
7. How to measure voltage, frequency and pulse width with the AN/ USM-117.
8. How to display Lissajous patterns.

TOPIC 9: OSCILLOSCOPE, TEKTRONIX 545A

The Tektronix 545A Oscilloscope is a wide-range general purpose laboratory instrument. It provides accurate measurements in the DC to 30 MC range and can be operated with any Tektronix letter series plug-in unit to satisfy the requirements for virtually any application.

Refer to the drawing of Tektronix Oscilloscope, Block Diagram on page 99. The 545A oscilloscope provides two time bases (A and B) that can be used independently or in conjunction with each other. When used together they permit an accurate, continuously variable delay in the presentation of the sweep from one microsecond to ten seconds after receipt of a triggering pulse. This feature permits observation of a small portion of the normal sweep, accurate measurement of waveform jitter, and precise time measurement as well as many other uses.

The horizontal deflection system for Time Base A provides a sweep range of 0.1 microsecond to 5 seconds per centimeter in 24 accurately calibrated steps. An uncalibrated control permits the sweep rate to be varied continuously between 0.1 microsecond and approximately 12 seconds per centimeter.

The horizontal deflection system for Time Base B provides a sweep range of 2 microseconds to one second per centimeter in 18 accurately calibrated steps. A VARIABLE LENGTH control permits the sweep length to be varied from 4 cm to 10 cm (10 cm is maximum horizontal deflection for both time bases).

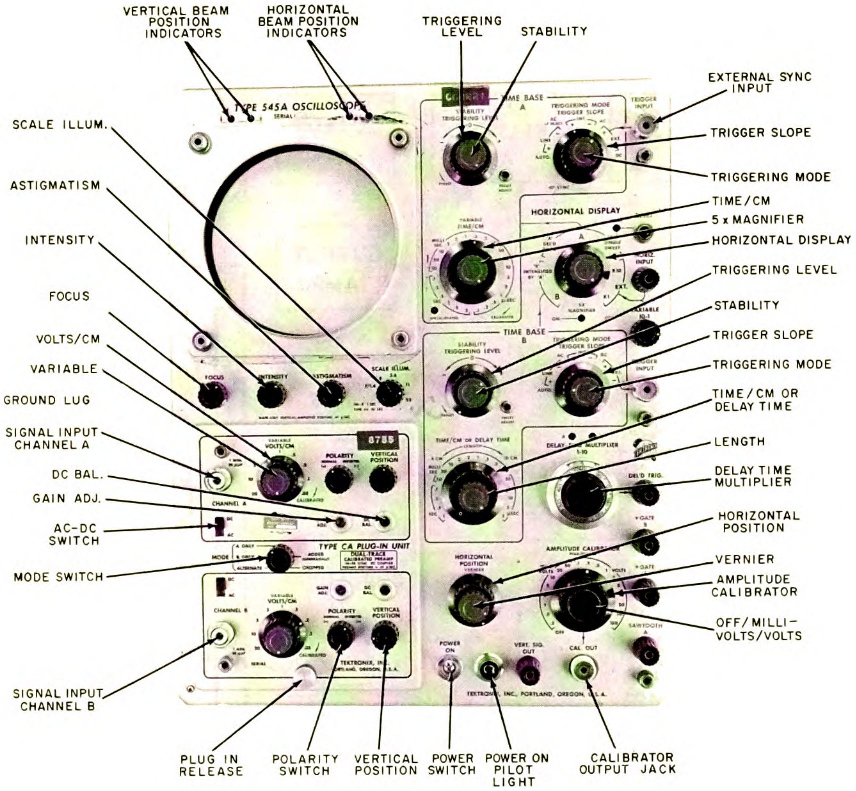
The sweep speed of each time base may be further extended with the use of the MAGNIFIER control. When turned on, the 5X magnification magnifies the center 2-centimeter portion of the oscilloscope display. Using this control increases the sweep rate of Time Base A to 0.02 microsecond per centimeter and increases Time Base B sweep rate to 0.4 microsecond per centimeter.

To initiate the horizontal display for Time Bases A or B, a trigger is used that may be derived from one of three sources; EXT., INT., or LINE. The source used is selected by the TRIGGER SLOPE switch; this control also selects the slope (positive or negative) of the triggering signal that is used to initiate the sweep.

Used in conjunction with the TRIGGER SLOPE control is the TRIGGERING MODE control. Time Base A has five triggering modes; AUTO, AC, DC, LOW FREQUENCY REJECT and HIGH FREQUENCY SYNC, while Time Base B has three; AUTO, AC and DC. Each of the triggering modes is designed to provide stable triggering from a certain type waveform. The mode used is a matter of choice and is selected on the basis of whether or not it allows you to obtain the desired display.

The vertical display for the CRT is derived from a plug-in pre-amp unit. There are a number of pre-amps available for use with the 545A oscilloscope; however in this text we are only concerned with those most commonly used in the maintenance of fire control equipment. Therefore, we will limit our discussion to the type 53/54C plug-in pre-amp.

OSCILLOSCOPE, TEKTRONIX 545A



Oscilloscope Tektronix 545A

50.—Oscilloscope 545A.

The type 53/54C plug-in unit is a dual trace preamplifier that consists of two identical amplifier channels (A andB). Each channel has its own positioning and attenuation controls that operate independently of the other channel. The controls of interest mounted on the front panel are marked as follows:

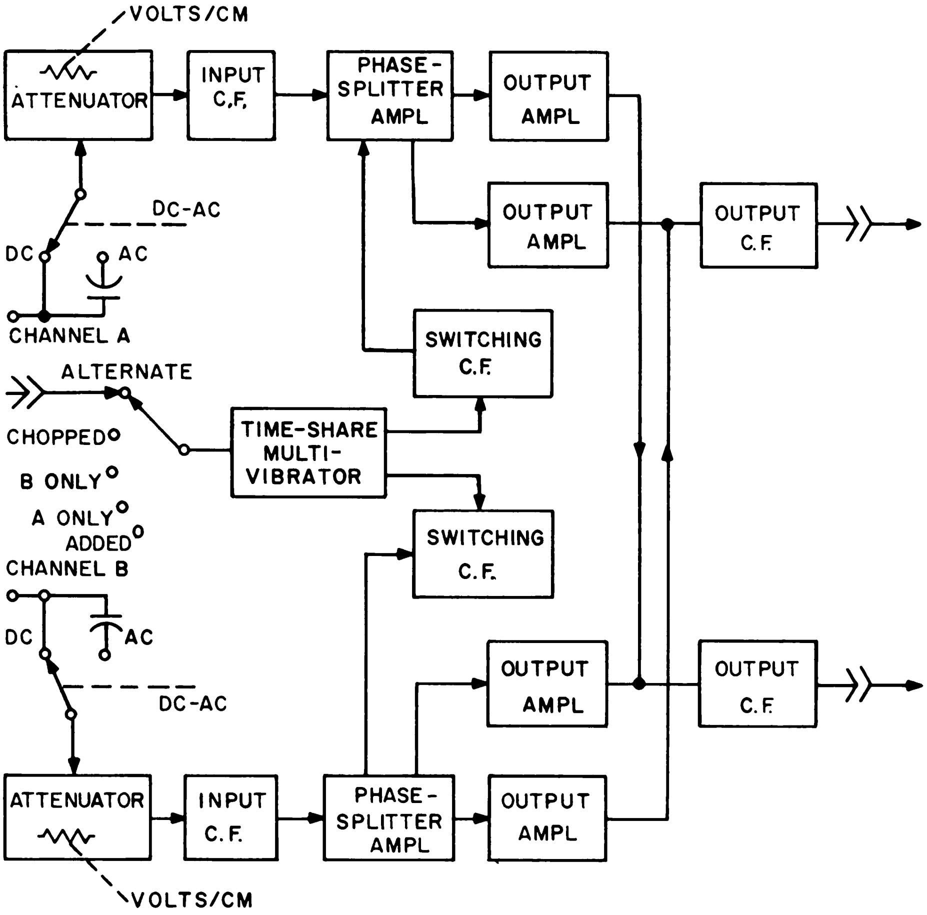
a. CHANNEL A (OR B): signal input jack to the A or B channel amplifiers.

b. DC-AC switch: slide switch to provide either AC or DC coupled input into the amplifier.

c. VOLTS/CM: nine position switch used to select the calibrated vertical-deflection sensitivities; has a range of 0.05V/cm to 20V/cm.

d. POLARITY: two position switch to provide optional in-phase or out-of-phase display on the CRT.

e. VERTICAL POSITION: potentiometer to provide for shifting the position of the trace vertically.



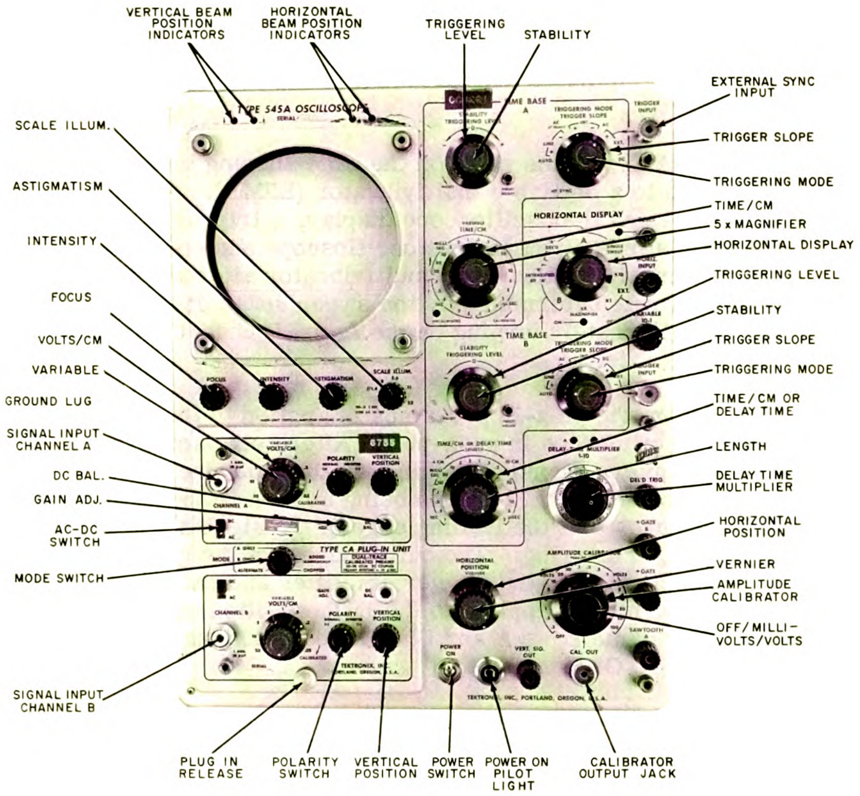
51.—Dual-Trace Preamplifier.

f. MODE switch: five position switch to allow either channel to be used independently, to provide for switching the two amplifiers at an arbitrary rate, to synchronize the switching with the oscilloscope sweep, or to add the two inputs and display the sum as one trace. The five positions are: A only, B only, alternate, chopped, and added algebraically.

The remaining controls on the front panel are screwdriver adjustments used when aligning the scope itself and should not be adjusted.

Since the dual amplifier channels are identical only the operation of one channel will be described. (Refer to the drawing of the Dual Trace Preamplifier.) The input video signal is applied to the attenuator control via the DC-AC switch. When in the AC position, a DC blocking capacitor is placed into the input circuit and the DC level of the input signal is blocked. Hence only the AC signal will be passed and no DC level can be

OSCILLOSCOPE, TEKTRONIX 545A



Oscilloscope Tektronix 545A

52. —Oscilloscope 545A.

measured. In the DC position the blocking capacitor is bypassed and the DC level is applied to the attenuator control.

The amount of attenuation is controlled by the VOLTS/CM switch and is set to give the required vertical deflection on the CRT. The attenuated output is applied to a phase splitter amplifier via an input cathode follower.

The phase splitter amplifier provides a push-pull output that is amplified by the output amplifiers and applied to the vertical amplifiers of the oscilloscope via the impedance matching cathode followers.

The type of display that is presented on the oscilloscope is determined. by the setting of the MODE switch on the front panel of the plug-in unit. Each position of this switch is discussed separately in the following discussion.

a. A ONLY OR B ONLY: in this position the time sharing multivibrator is maintained in one of its two stable states. In the A ONLY position a 0 volt enabling signal is applied to the A channel phase splitter amplifier via the switching cathode follower. At the same time, a disabling positive pulse is applied to channel B. In the B ONLY position the above action is reversed.

b. CHOPPED POSITION: in this position, the time sharing multivibrator is allowed to "free run" at a 100 KC rate. The A and B channel amplifiers are therefore alternately turned on and off at this rate.

c. ALTERNATE: in this position the time sharing multivibrator is converted to a bi-stable multivibrator (BSMV). At the end of each sweep on the oscilloscope display, a trigger is generated in the main sweep circuit of the oscilloscope and coupled to the time sharing multivibrator. The multivibrator alternately changes state at a rate determined by the sweep speed of the CRT display thereby alternately turning on the A and B channel amplifiers at this same rate.

The signal from the plug-in pre-amps is applied to the input vertical amplifier of the oscilloscope in push-pull. After being amplified it is applied to the 0.2 microsecond delay line via the grid line driver amplifiers. The delay of the signal prior to being applied to the vertical deflection plates ensures that the leading edge of the signals will be displayed when using internal triggering. The output signal of the grid line driver amplifiers is also applied to the trigger amplifier and cathode follower circuit. The signal is then applied to the INT. position of the TRIGGER SLOPE control for Time Base A and B. The output signal is also available at the VERT SIG OUT jack.

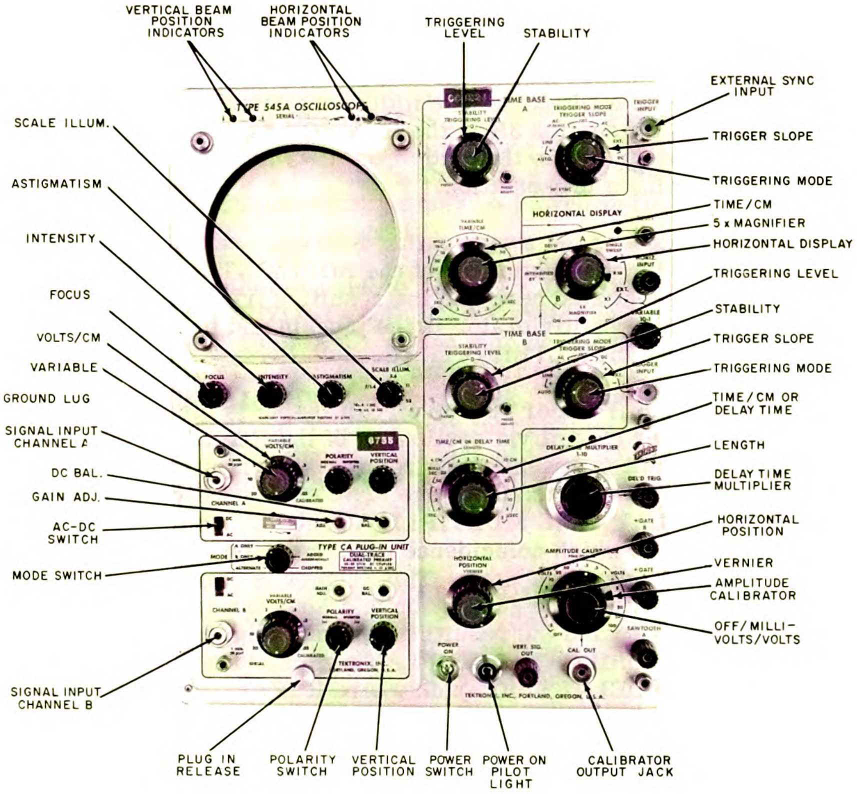
The HORIZONTAL DISPLAY switch in the illustration is in the Time Base B position. Therefore that time base will be discussed here. Time Base A is similar.

From the INT. position of the TRIGGERING SLOPE control the signal is amplified by the trigger input amplifier and is applied to the trigger multivibrator. The TRIGGERING MODE control determines the circuit parameters of the trigger input amplifier, while the TRIGGERING LEVEL control determines the bias of the amplifier. Upon receipt of the trigger, the trigger multivibrator produces a square wave output. This output is differentiated and the resulting negative trigger is used to flip the sweep gating BSMV. The output of the BSMV will gate on a "Miller run-up" circuit, which will generate a sawtooth voltage. The width of this sawtooth waveform (or sweep speed) is controlled by the TIME/CM control.

To prevent the sweep gating BSMV from being flipped by every input trigger and thereby ending the sawtooth waveform, a hold-off circuit is used. This circuit receives the sawtooth output of the Miller run-up circuit and applies it to the input circuit of the sweep gating multivibrator as a bias voltage. At the time that the sawtooth waveform reaches its predescribed value, thereby providing full scale deflection on the face of the CRT, the bias on the sweep gating multivibrator will be lowered sufficiently to allow the next input trigger to flip it. When the BSMV flips, the circuit is returned to its static state, and upon receipt of the next input trigger the circuit will be activated again.

The TIME/CM control determines the sweep speed (duration of the sawtooth output) by selecting various RC networks in the plate and grid

OSCILLOSCOPE, TEKTRONIX 545A



Oscilloscope Tektronix 545A

53. —Oscilloscope 545A.

circuits of the Miller run-up-circuit. These RC networks vary the amount of time necessary for the sawtooth output from the Miller run-up circuit to reach a value of voltage sufficient to provide 10. cm of horizontal deflection on the CRT.

The SWEEP LENGTH control of only Time Base B can be varied by the SWEEP LENGTH control from 4 to 10 cm. This control varies the level of bias voltage applied to the sweep gating BSMV thereby determining which input trigger will initiate it. This action results in the sawtooth output ending before it has reached a value of voltage sufficient to deflect the CRT electron beam the full 10 cm.

The output of the Miller run-up circuit is applied to the horizontal amplifier via section 2R and 1F and R of the HORIZONTAL DISPLAY switch. The horizontal amplifier amplifies the sawtooth voltage and applies it to the horizontal deflection plates of the CRT. The HORIZONTAL POSITION control varies the position of the display by changing the DC level to which the sawtooth waveform is clamped. The 5X MAGNIFIER control essentially does the same thing; however it also increases the magnitude of the sawtooth output voltage. The result is that the center 2 cm display is expanded to cover the full 10 cm's.

The sweep gating multivibrator for Time Base B has two outputs in addition to the one applied to the Miller run-up circuit. One output is applied to the +gate output cathode follower where it is applied to an external jack; and also to the unblank cathode follower. From here it is applied to the CRT circuits via section 3R of the HORIZONTAL DISPLAY switch. This pulse will be applied to the grid of the CRT and will turn the beam on, thereby allowing a presentation.

The other output of the sweep gating BSMV is sent to the alternate trace sync amplifier via section 4R of the HORIZONTAL DISPLAY switch. The pulse is differentiated here and the resulting trigger is used to trigger the time sharing multivibrator in the plug-in and pre-amp when the MODE control is in the ALTERNATE position.

The Time Base B Miller run-up circuit output is also applied to a difference amplifier circuit via section 2F of the HORIZONTAL DISPLAY switch. This circuit is essentially a comparison circuit that will generate a trigger when the sawtooth voltage level equals the voltage level controlled by the DELAY TIME MULTIPLIER control. As this control is variable the level at which coincidence occurs can be varied, thereby varying the output trigger in time. This trigger is applied to the delayed trigger MSMV to initiate the generation of a square wave. The square wave is differentiated and the resulting negative trigger is applied to the 1F section of the HORIZONTAL DISPLAY switch. The output trigger is also applied to the DEL'D TRIG. jack where it is available for external use.

When the HORIZONTAL DISPLAY switch is in the Time Base A position, circuit operation is similar to that described for Time Base B except that Time Base A circuits are used.

In the B INTENSIFIED BY A position of the HORIZONTAL DISPLAY switch, the following action takes place. (During the following discussion it is assumed that the Time Base A TIME/CM control is set at a faster sweep than the Time Base B control.) The circuit operation for Time Base B is identical as that previously discussed. The exception is that the delayed trigger from the delayed trigger MSMV is applied to the delayed trigger amplifier via section 1F of the HORIZONTAL DISPLAY switch. Also during this mode the lock-out multivibrator is functioning and prior to receiving a delayed trigger is holding the sweep gating BSMV for Time Base A in the off position. Upon receipt of the delayed trigger, the lock-out multivibrator flips and allows the Time Base A sweep gating BSMV to also flip. The width of the output pulse at this time depends upon the setting of the Time Base A TIME/CM control. The output square wave is then applied to section 3R of the HORIZONTAL DISPLAY switch via the unblank cathode follower. From here this unblank pulse is added to the unblank pulse from Time Base B and will be applied to the CRT circuits. When the sum of these two output pulses is applied to the CRT grid it will result in the Time Base B sweep (which covers the entire 10 cm face of the CRT) being intensified by the Time Base A unblank pulse. The width of the intensification is determined by the Time Base A TIME/CM control while the position will be determined by the DELAY TIME MULTIPLIER control. By varying the latter control the intensification can be positioned to any place on the sweep.

After setting the intensified portion to the position desired, the HORIZONTAL DISPLAY switch may be positioned to the A DELAYED BY B position. The intensified portion of the preceding position of the switch will now cover the entire 10 cm of the CRT. This is accomplished by removing the sawtooth sweep voltage from Time Base B to the horizontal amplifier and substituting the sawtooth voltage from Time Base A. In this position the sweep presentation may be moved in time by turning the DELAY TIME MULTIPLIER control.

This scope may also be used to present a Lissajous pattern. To accomplish this, the HORIZONTAL DISPLAY switch is placed into the EXT. position (either the X 10 or X 1 position may be used). This removes the sawtooth sweep from the horizontal amplifier and substitutes a signal from the HORIZONTAL INPUT external jack. By applying a signal to this jack that is 90 degrees out of phase with that applied to the plug-in preamp, a circle may be obtained on the face of the CRT. The amplitude of the input signal from the HORIZONTAL INPUT jack can be varied prior to being applied to the horizontal amplifier by varying the 10:1 ATTENUATOR control.

The positions of the HORIZONTAL DISPLAY switch that have been discussed in the previous paragraphs are those that are most commonly used by the fire control technician. The remaining positions are seldom used, and therefore are not discussed in this text.

OSCILLOSCOPE, TEKTRONIX 545A

To properly use the Tektronix 545A Oscilloscope, it is imperative that the trainee have a knowledge of time base diagrams, and the associated definitions. The oscilloscope display is a time base diagram which displays a plot of voltage versus time. Voltage is displayed on the vertical axis, or ordinate, and the horizontal axis, or abcissa represents time. The dimension of the quantity time, is usually in u sec. Although it may be expressed in millisecond, seconds, or minutes.

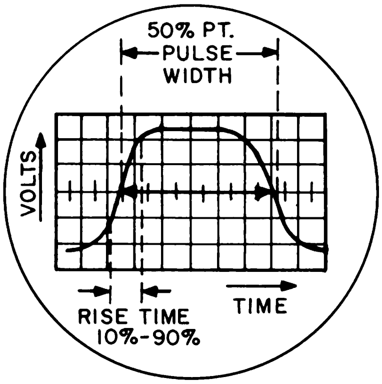
To determine if a circuit is operating properly, circuit waveshapes may be displayed on an oscilloscope. From the oscilloscope display it is possible to obtain a set of measurements which yields the desired information. When viewing a square wave the measurements that can be made are:

1. Rise time
2. Pulse width
3. Fall time or decay time
4. Pulse jitter

Rise time is usually defined as the time it takes for the voltage to rise from the 10% point to the 90% point of the leading edge of the wave. In some cases, the rise time will be taken from the 1 DB point to the 6 DB point. The faster the rise time, the shorter the amount of time it takes the voltage to rise from the 10% to 90% points. Rise time of a pulse is given in u sec.

The pulse width is usually measured from the 50% point of the leading edge to the trailing edge of the square wave. Pulse width is given in u sec. The wider the pulse width, the longer the time duration of the pulse.

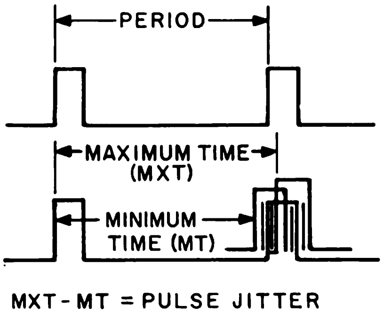
The decay time is usually defined as the time it takes the voltage to fall from the 80% to the 10% points of the square wave trailing edge. Decay time is given in u sec. The smaller the decay time, the steeper the slope of the trailing edge.



54. —Time Base Diagram.

The time interval between two given pulses is defined as the pulse interval or period.

The amount the pulses vary in time with respect to each other, is called pulse jitter. Pulse jitter may be due to a variety of causes. But if the jitter is excessive it may have serious effects on the reliability of a radar set.

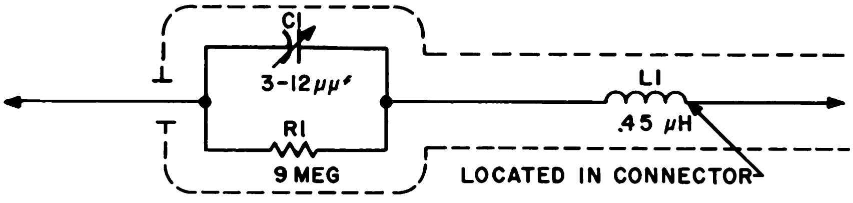


55. —Pulse Jitter Measurement.

Experiment 9-1—Probe Adjustment

In this experiment you will learn to adjust the Tektronix Low Capacitance Probe, Type P6000. You will see the effect or probe adjustment on the scope calibrator output waveforms.

An adjustable capacitor in the probe body, below, compensates for variations in input capacitance from one instrument to another. To insure the accuracy of pulse and transient measurements, this adjustment should be checked frequently.

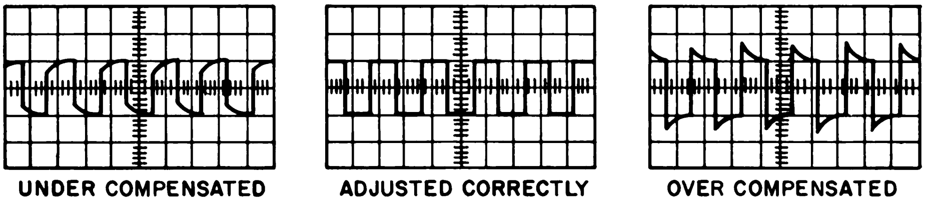


56. —Low Capacitance Probe, Type P6000, Schematic Diagram.

Experiment 9-1—Probe Adjustment (Continued)

To adjust the P6000 probe, set the Calibrator control for a calibrator output signal of suitable amplitude. Touch the probe tip to the CAL. OUT connector and adjust the oscilloscope controls to display several cycles of the waveform. Unlock the probe for adjustment by turning the locking sleeve at the rear of the probe body 4 or 5 turns counterclockwise. Hold the probe firmly by the notched flange at the base of the probe, and adjust by turning the probe barrel for an optimum waveshape as shown in the center waveform illustration below.

After a good flat-top square wave is achieved, turn the locking ring clockwise until it is fairly tight but not too tight. Holding the probe by the barrel, make fine adjustments by turning the notched flange. Carefully tighten the locking ring.



57. —Probe Adjustment Waveforms.

Review

In this topic you have studied the Tektronix 545A Oscilloscope.

The main points you should have learned include:

1. The capabilities and special features of the Tektronix 545A Oscilloscope.
2. The names, function and use of the various front panel controls.
3. Description, signal flow and modes of operation of the dual trace plug in preamplifier.
4. Description, signal flow and modes of operation of the 545A Oscilloscope.
5. Construction, adjustment and use of the P6000 low capacitance probe.
6. Measurement of rise time, pulse width, decay time and pulse jitter.

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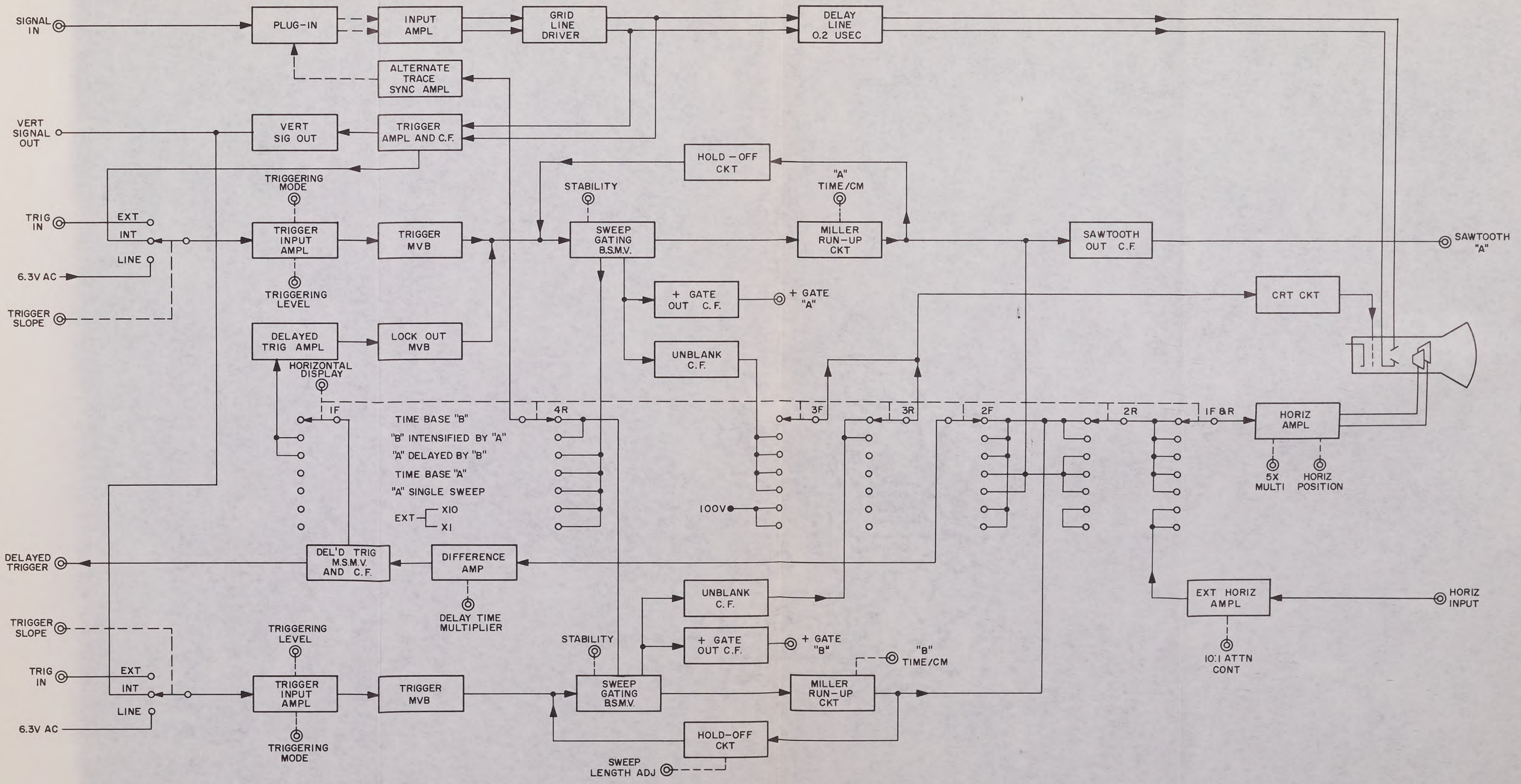

58. OSCILLOSCOPE 545A, BLOCK DIAGRAM

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